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# SPACE SHUTTLE AFRSI OMS POD ENVIROMENT TEST USING MODEL 81-0 TEST FIXTURE IN THE AMES RESEARCH CENTER 9x7-FOOT SUPERSONIC WIND TUNNEL (OS-314A/B/C)

(NASA-CR-167689) SPACE SHUTTLE AFRSI OMS POD ENVIRONMENT TEST USING MODEL 81-0 TEST FIXTURE IN THE AMES RESEARCH CENTER 9X7-FOOT SUPERSONIC WIND TUNNEL (OS-314A/B/C) (Rockwell International Corp.) 83 p HC A05 00/16 N84-34464 Unclas 24099

by

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by

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for

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Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas

WIND TUNNEL TEST SPECIFICS:

| | |
|---|---|
| Test Number | 582-1-97-ARC |
| NASA Series Number: | OS-314 |
| Model Number: | 81-0 |
| Test Dates: | 5/24/83 to 6/3/83, 7/19/83, 7/27/84 |
| Occupancy Hours: | 96 |

FACILITY COORDINATION:

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SPACE SHUTTLE AFRSI OMS POD ENVIROMENT TEST
USING MODEL 81-0 TEST FIXTURE IN THE
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## ABSTRACT

A test was conducted in the NASA/Ames Research Center 9x7-foot Supersonic Wind Tunnel to help resolve an anomaly that developed during the STS-6 orbiter flight wherein sections of the Advanced Flexible Reusable Surface Insulation (AFRSI) covering the CMS pods suffered some damage. A one-third scale two-dimensional shell structure model of an OMS pod cross-section was employed to support the test articles. These consisted of 15 AFRSI blanket panels form-fitted over the shell structure for exposure to simulated flight conditions.

Of six baseline blankets, two were treated with special surface coatings. Two other panels were configured with AFRSI sections removed from the OV099 orbiter vehicle after the STS-6 flight. Seven additional specimens incorporated alternative designs and repairs.

Following a series of surface pressure calibration runs, the specimens were exposed to simulated ascent and entry dynamic pressure profiles. Entry conditions included the use of a vortex generator to evaluate the effect of shed vortices on the AFRSI located in the area of concern.

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# INTRODUCTION

Advanced Flexible Reusable Surface Insulation (AFRSI) has been developed as a replacement for the Low-Temperature Reusable Surface Insulation (LRSI) tiles on the Space Shuttle Orbiter Vehicle. AFRSI is a quilted blanket consisting of silica fiber insulation material with a quartz fabric outer mold line (OML) and a glass fabric inner mold line (IML) lining. The quilting is done with quartz thread stitched through the three layers of material. The blanket IML is bonded to the skin of the vehicle while the OML face is exposed to the high pressure gradients, fluctuating acoustic pressures, and wind shear stresses attendant to atmospheric flight. So far, AFRSI has been employed only in small selected areas of the Shuttle Orbiter. An anomaly developed during the STS-6 flight wherein sections of AFRSI covering the OMS pods suffered some damage.

The purpose of this test was to gain some insight into the possible causes of the problem by:

1. Obtaining detail pressure gradient loadings and acoustic pressure levels data at the forward end of the OMS pods.

2. Evaluating the effect of shed vortices on the AFRSI located in the area of concern.

3. Subjecting alternate AFRSI blanket designs to the aerodynamic environment at the OMS pods.

The test reported herein was conducted in three phases, A, B, and C, at the NASA/ARC 9x7-foot Supersonic Wind Tunnel between May 24 and July 27, 1983. Fifty-one runs were completed during 96 hours of occupancy.

The test articles consisted of AFRSI blanket panels form-fitted over a shell structure that was contoured to represent a 1/3-scale two-dimensional model of an OMS pod cross-section. The shell was attached to the model 81-0 trailing edge flap located on the ceiling of the tunnel. A 23-degree deflection of the flap was required to expose the true scale OMS pod contour to the tunnel airflow. A rectangular airfoil section mounted perpendicularly to the forward flat surface panel of the Model 81-0 fixture, was used to generate a vortex which was allowed to impinge on the contoured AFRSI.

A separate instrumented panel was fitted over and attached to the contour shell for flow visualization and pressure calibration purposes. Local surface static and fluctuating pressures were measured.

The test articles were exposed to simulated ascent and entry dynamic pressure profiles with peaks of 550 psf for ascent, 650 psf for design ascent, 160 psf for entry without vortex generator, and 110 psf with shed vortices simulation. All specimen testing was conducted at a constant Mach number of 2.5.

The data acquired during the test is being analyzed by the Orbiter Aerodynamics, the Vibro-Acoustics, and the TPS Test Design and Requirements units of Rockwell. Conclusions and recommendations will be made by these same units under separate reports.

This report contains information on the conduct of the test, details of the model and instrumentation, and photographs of the specimens tested.

## NOMENCLATURE

| SYMBOL | MNEMONIC | DEFINITION |
|---|---|---|
| $C_p$ | CP | Pressure coefficient |
| $M$ | MACH | Freestream Mach number |
| $P_\infty$ | P | Freestream static pressure, psia |
| $P_\ell$ | PL | Local static pressure, psia |
| $P_{RMS}$ | PRMS | RMS value of the variations from the mean value of the local pressure, psi |
| $P_t$ | PT | Freestream total pressure, psia |
| $q$ | Q | Freestream dynamic pressure, psf |
| $R_e$ | RE | Freestream Reynolds number, per ft |
| $T_s$ | TS | Freestream static temperature, deg R |
| $T_t$ | TT | Freestream total temperature, deg R |
| $V_\infty$ | V | Freestream velocity, ft/sec |
| $X$ | X | Longitudinal distance, positive aft of forward panel L.E., inches |
| $X_c$ | XC | Longitudinal distance, positive aft of contour panel L.E., inches |
| $Y$ | Y | Lateral distance, positive right of the model centerline, inches |
| $Z$ | Z | Vertical distance, positive above the plane of the forward panel, inches |
| $\delta_f$ | DF | Flap angle, deg |
| $\delta_v$ | DV | Vortex generator angle, deg |
| $\rho$ | RHO | Freestream density, slugs/ft$^3$ |

## REMARKS

The flow visualization tests using oil emanating in the compression corner of the model were unsuccessful. The pressure imparted to the oil streams was insufficient to overcome the reverse airflow pattern created near the boundaries of the contour shell/forward plate intersection. Somewhat improved results were obtained by applying the oil directly on the model. The difficulty with this latter method was that most of the flow patterns observed were largely those generated with the model retracted ($\delta_f$=0) while the tunnel was being brought up to the test condition.

Minor malfunctions of the static pressure instrumentation on the test fixture were experienced:

1. During the first entry (OS-314A), pressure taps 19 and 51 did not function properly. Also, the output of tap 35 was lost after the flow visualization tests.

2. Pressure taps 6, 19, 35, and 51 malfunctioned during the second entry (OS-314B).

3. The same four taps (6, 19, 35, 51) and tap 8 were defective during the third entry (OS-314C).

The mechanics involved in bringing the wind tunnel up to speed and in stopping the tunnel flow, made it impossible to generate a faithful simulation of a single-mission ascent dynamic pressure profile. The tunnel simply took too much time to reach the dynamic pressures that were required for this test. A procedure was evolved wherein the freestream dynamic pressure could be increased and decreased as rapidly as practicable in order to minimize the

differences between the tunnel and the orbiter flight profiles. Still, the results obtained were more representative of multi-mission loading accumulations than the single missions that were sought.

## CONFIGURATIONS INVESTIGATED

### Model Description

Model 81-0 (drawing L014-01496) as modified in June 1981 and May 1983, was employed for this test. The fixture, located in the ceiling of the wind tunnel, consists of a 12-inch chord flap with a 63-inch span mounted at the trailing edge of a specimen-holding frame, and a sealed pressure box enclosing the space above the holding frame. The pressure box was vented to the tunnel test section to permit pressure equalization across the plate ahead of the flap (see Figure 1).

The flap, hinged on the ceiling, can be rotated from 0 to 90 degrees by a remotely controlled hydraulic actuator. This component of the test fixture was modified to serve as a mounting surface for a contour shell to which the pressure calibration panel and the AFRSI specimens were attached. This contour shell was designed to represent a scaled two-dimensional model of an OMS pod cross-section ($X_o$=1310 to 1410) taken at a radial angle of 120 degrees measured from $Y_o$=0, $Z_o$=400. The shell was sized such that when covered with an AFRSI blanket, the contour yielded a 1/3 scale of the outer mold line (OML) of the OMS pod cross-section, when the flap was deflected at 23 degrees. The shape of the selected contour is shown in Figure 5, together with a tabulation of the surface contour coordinates.

To compensate for the 6.77-inch depth of the supporting frame inside the test fixture, a 4.5-inch spacer was used together with appropriate shims to bring the edges of the forward panel flush with the surface of the test fixture.

For flow calibration purposes, an instrumented panel is available for mounting in the specimen-holding frame. For the present test, this panel was placed in the holding frame and remained there for the duration. A rectangular airfoil section mounted perpendicularly to the surface panel ahead of the flap was used to generate a vortex which was allowed to "scrub" the model OMS pod surface near the centerline. Four such vortex generators (VG) were tested: one symmetrical wedge-shape, and three cambered airfoils with flat lower surfaces.

| VG No. | | Span | Chord |
|---|---|---|---|
| -4 | Cambered | 2.5 in. | 4.5 in. |
| -7 | Wedge | 3.5 in. | 14.0 in. |
| -10 | Cambered | 7.0 in. | 7.0 in. |
| -11 | Cambered | 7.0 in. | 14.0 in. |

Each airfoil section had a one-inch maximum thickness at 40 percent chord and a circular leading edge with a radius equal to 2.5 percent chord. All VG's were mounted at 40 percent of their respective chords on a pivot located at 4.9 inches aft of the leading edge of the forward plate and offset 1.45 inches from the centerline. A remotely controlled hydraulic actuator enabled the support stem and the VG's to be rotated (or oscillated) up to ±45 degrees. A schematic of the VG is shown in Figure 3.

## Test Specimens

The baseline AFRSI blankets consist of silica fiber felt (Q-felt) insulation material with a silica cloth covering and a glass cloth back lining, all quilted together with quartz thread in a one-inch square grid pattern. The quilting is done with a modified lock stitch. The outer covering is made of material 0.027 inch thick with a weight of 20 ounces/square yard.

## CONFIGURATION INVESTIGATED (Concluded)

The test articles consisted of AFRSI panels (34x30 inches) bonded with RTV to 3/16-inch baseplates such that the stitching loops were embedded in the bonding material. Two-inch foam frames surrounded the panels leaving an exposed AFRSI surface 30x26 inches. The panels were form-fitted over the contour shell to which they were attached with bolts inserted through the bordering frames. The maximum thickness of the AFRSI blanket material in the specimens was 0.92 inch (see Figure 6).

Fifteen interchangeable AFRSI specimens were tested. Nine during the first entry (OS-314A), and three in each of the two subsequent entries (OS-314B, C). The specimens could be divided into three general categories:

1. Six baseline configuration panels, two of which were treated with special surface coatings.

2. Two test articles configured with AFRSI sections removed from the orbiter vehicle (OV099) OMS pods following the STS-6 flight.

3. Seven specimens incorporating alternative designs and repairs for evaluation purposes.

The characteristics of the specimens are described in Table I. Photographs of the specimens taken before and after testing are shown in Figures 13a. through 13zz.

An instrumented panel made of fiberglass covered foam of the same thickness as the AFRSI specimens was fitted over and attached to the contour shell for pressure calibration and flow visualization purposes (see Figure 7). A schematic of the test installation is shown in Figure 2 and a model/specimen installation is illustrated in Figure 4.

## INSTRUMENTATION

The model test fixture and the calibration panels were instrumented for static and fluctuating pressure measurements. The layouts and the location coordinates of the instrumentation are shown in Figures 7 and 8 and listed in Tables II and III.

### Static Pressure

The test installation was instrumented with 108 static pressure taps distributed as follows:

| | |
|---|---|
| Test Fixture | 9 |
| Forward Plate | 38 |
| Contour Panel | 61 |

The taps on the contour panel were connected to a separate Scanivalve assembly located inside the contour shell structure. This assembly was removed following the calibration runs. The other Scanivalve, bolted to the top of the ceiling hatch outside the tunnel, measured the other pressures and remained active throughout the test.

### Fluctuating Pressure

The fluctuating pressure instrumentation consisted of 56 Kulite transducers distributed as follows:

| | |
|---|---|
| Test Fixture | 7 |
| Forward Plate | 15 |
| Contour Panel | 34 |

The transducers on the contoured calibration panel were disabled after the calibration runs were completed.

Flap and VG Deflections

Each of the flap and the airfoil VG drive systems were equipped with a position transducer to measure the angular deflections of the surfaces.

Visual Records

A video camera was positioned to record on a time-coded videotape, the condition of the test articles during the runs. In order to obtain data on the mechanism of AFRSI failures, a high-speed movie camera was activated upon visual observation of the onset of a failure on a test pad.

## TEST FACILITY DESCRIPTION

The 9x7-foot Supersonic Wind Tunnel is one of the supersonic legs of the Ames Unitary facility. It is a closed-circuit, variable-density, continuous-flow tunnel. The test section is 9 feet wide by 7 feet high by 18 feet long and the nozzle is of the asymmetric, sliding-block type, in which the variation of the test section Mach number is achieved by translating, in the streamwise direction, the fixed contour block that forms the floor of the nozzle. The temperature is controlled by after-cooling. Dry air for use in the circuit is supplied from four 30,000 cubic-foot spherical tanks. The tunnel drive motors and compressor also serve the 8x6-foot tunnel. The motors have a combined output of 180,000 horsepower for continous operations or 216,000 horsepower for one hour of operation.

Following the pressure calibration runs, the fixed contour block was positioned to provide the nozzle throat required to achieve a constant Mach number of 2.5. The purpose was to minimize the time needed to achieve the specified dynamic pressure conditions at that Mach number.

## TEST CONDITIONS AND PROCEDURES

Calibrations were carried out to determine the flow characteristics on the model surface under parametric freestream conditions and model orientations. These tests were conducted at Mach numbers ranging from 1.8 to 2.5 for dynamic pressures of 200 to 600 psf while varying the OMS pod contour incidence (flap angle) from zero to 37 degrees and vortex generator angles from -10 to +15 degrees. Pressure data was also obtained for the model configured without a vortex generator.

Oil flow visualization tests were made at Mach number 2.5 and a dynamic pressure of 300 psf for flap deflections of zero and 23 degrees, and VG angles of zero and 15 degrees.

Preliminary calibration data analysis led to the decision to conduct the specimen testing at a constant Mach number of 2.5 with the OMS pod model incidence set at 23 degrees, and to employ the wedge-shape airfoil model (VG-7) where a vortex generator was called for. Where no VG was required, the airfoil was to be set at zero degree or removed from the model.

The following general procedure was implemented for testing the specimens. To avoid high starting loads being imposed on the model, the flap was set at zero degree and the tunnel pumped down to approximately 10 inches Hg before initiating drive start. With the tunnel on line, its total pressure was further decreased to 7 inches Hg, which was maintained until supersonic flow was achieved. At this point, the OMS pod model was lowered into the freestream ($\delta_f$=23 degrees) and the total pressure increased as rapidly as possible until the the desired dynamic pressure was achieved. Similarly, the return to lower q

values was effected by decreasing the pressure to 7 inches Hg at which point the OMS pod model was retracted to zero incidence and a fast stop procedure was initiated.

The nominal ascent simulation required a q increase to 550 psf and an immediate return to the lower values. In some instances, a maximum design q of 650 psf was specified. For re-entry, maximum dynamic pressures of 110 psf (with VG) and 160 psf (without VG) were required. Multi-mission requirements were met by holding the maximum q condition for the time stipulated, with the provision that the run was to be aborted when damage to the specimen was observed.

The dynamic pressure loading profiles for entry, ascent, and design ascent are shown in Figures 10 through 12. The methodology employed to compute the number of ascent mission loadings related to tunnel exposure time is outlined in the four charts which constitute Table V.

A summary of the runs completed, including the test conditions, is shown in Table IV.

## DATA REDUCTION

Standard tunnel equations were used to compute all tunnel conditions.

Local static pressure data were reduced to standard coefficient form,

$$C_p = (P_\ell - P_\infty) * 144/q$$

RMS fluctuating pressure data were reduced to coefficient form and to DB form

$$DB = 10 \log_{10} \left[ \frac{P_{RMS} \times 10^9}{2.9007} \right]^2$$

These RMS data were recorded continuously on magnetic tape and analyzed by Rockwell's Vibration and Acoustics unit (Department 380).

# RESULTS

Results of the tests are summarized in Table VI. Pre-test and post-test photographs of the samples tested are included in Figures 13a through 13zz. No pre-test photos of test articles J and M, and no post-test photos of C, E, and M are available.

The higher Mach number was selected because the data at Mach 2.5 showed close agreement of peak reattachment pressures with STS-6 predictions (see Reference 3). The selection of the maximum dynamic pressures was dictated by the requirements for specific shock amplitudes and acoustic pressure levels (References 2 and 3). The calibration results shown on Figures 14 through 17 were adjusted to achieve the following test conditions:

| | $\Delta P$ | Acoustic | q |
|---|---|---|---|
| Entry (w/o VG) | 0.63 psi | 154 db | 160 psf |
| Entry (w/VG) | 0.58 psi | 153 db | 110 psf |
| Ascent | 2.15 psi | 164 db | 550 psf |
| Design Ascent | 2.58 psi | 166 db | 650 psf |

Note that these pressure levels were obtained at tunnel dynamic pressures approximately 20 percent lower than the flight q's (Figure 18).

REFERENCES


1. STS83-0322, "Pretest Information for the AFRSI OMS Pod Environment Test OS-314 in the Ames Research Center 9x7-ft Wind Tunnel Using Model 81-O Test Fixture," April 1983

2. SAS/AERO/84-047, "Data Analysis Summary for the AFRSI OMS Pod Environment Test OS-314 in the ARC 9x7-ft UPWT," February 1984

3. V&A-280-301-84-050, "Dynamic Calibration for the OS-314 AFRSI OMS Pod Fixture in the ARC 9x7-ft Wind Tunnel," April 1984

TABLE I

CHARACTERISTICS OF TEST SPECIMENS
(See Flexible Insulation Specification MB0135-085)

Fabric - Top Cover: Quartz, 0.027 inch (20 oz/sq yd)
Bottom : S-Glass, 0.009 inch (6 oz/sq yd)

Thread - OML : Quartz, 22 mils
IML : E-Glass, 20 mils

Stitching: Modified Lock Stitch

Thickness: 0.92-inch

| Test Pad | Configuration | Special Treatment |
|---|---|---|
| A | 1-inch Stitch Grid* | ** + RTV Coat |
| B | 1-inch Stitch Grid | ** |
| C | 1/2-inch Stitch Grid Lock Stitch Inside | ** |
| D | 1/4-inch Stitch Grid Alternate Stitches Lock-Stitched Outside | ** |
| F | 1-inch Stitch Grid* | ** + Ludox Coat |
| G,H,I | 1-inch Stitch Grid* | |
| J | Section Removed from OV099 (STS-6) | |
| K | 1/2-inch Stitch Grid 0.060 inch OML Face Sheet | |
| L | 1/4-inch Grid on Forward 12 inches - 1-inch Grid on Aft Section | ** |
| M | Section Removed from OV099 (STS-6) | |
| N | Repair Patches | |
| O | Joint Fixes | |
| 101 | 1/4-inch Stitch Grid Lock Stitch on IML | |

* Baseline Design
** Thermally Conditioned (1100°F)

TABLE IIa.

STATIC PRESSURE

INSTRUMENTATION COORDINATES (OS-314)

(Forward Panel)

| X \ Y | 14.62 | 12.0 | 6.0 | 0 | -6.0 | -12.0 |
|---|---|---|---|---|---|---|
| 6.0 | 1 | | | | | |
| 10.0 | 2 | | | | | |
| 14.0 | 3 | | | | | |
| 16.0 | 4 | | 13 | 22 | 40 | |
| 18.0 | | | | 23 | | |
| 20.0 | 5 | | 14 | 24 | 41 | |
| 22.0 | | | | 25 | | |
| 24.0 | 6 | 10 | 15 | 26 | 42 | 49 |
| 26.0 | | | | 27 | | |
| 28.0 | 7 | | 16 | 28 | 43 | |
| 30.0 | | | | 29 | | |
| 32.0 | 8 | 11 | 17 | 30 | 44 | 50 |
| 34.0 | | | | 31 | | |
| 36.0 | 9 | | 18 | 32 | 45 | |
| 38.0 | | | | 33 | | |
| 40.0 | | 12 | 19 | 34 | 46 | 51 |
| 42.0 | | | | 35 | | |
| 44.0 | | | 20 | 36 | 47 | |
| 46.0 | | | | 37 | | |

TABLE IIb.

STATIC PRESSURE
INSTRUMENTATION COORDINATES (OS-314)

(Contour Shell)

| X \ Y | | 12.0 | 6.0 | 0 | -6.0 | 12.0 |
|---|---|---|---|---|---|---|
| 49.48 | | 101 | 106 | 123 | 140 | 157 |
| 50.62 | | | 107 | 124 | 141 | |
| 51.99 | | | 108 | 125 | 142 | |
| 53.54 | | | 109 | 126 | 143 | |
| 55.20 | | 102 | 110 | 127 | 144 | 158 |
| 56.92 | | | 111 | 128 | 145 | |
| 58.69 | | | 112 | 129 | 146 | |
| 60.51 | | | 113 | 130 | 147 | |
| 62.37 | | 103 | 114 | 131 | 148 | 159 |
| 64.27 | | | 115 | 132 | 149 | |
| 66.19 | | | 116 | 133 | 150 | |
| 68.13 | | | 117 | 134 | 151 | |
| 70.07 | | | 118 | 135 | 152 | |
| 72.02 | | 104 | 119 | 136 | 153 | 160 |
| 73.98 | | | 120 | 137 | 154 | |
| 75.95 | | | 121 | 138 | 155 | |
| 77.92 | | 105 | 122 | 139 | 156 | 161 |

TABLE IVa TEST RUN SCHEDULE

DATE 6/3/83 TEST OS314A ARC 9x7

| | CONFIGURATION | | VG | $\theta_{OMS}$ | $\delta_v$ | CONDITION | DYNAMIC PRESSURE | TIME | MACH NUMBERS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ID | Description | No. | Deg | Deg | | (PSF) | (Seconds) | 1.8 | 2.0 | 2.2 | 2.5 |
| | | CALIB. PANEL | -4 | 23 | $V_1$ | | 600 | | 2 | 3 | 4 | 5 |
| | | | " | 0 | " | | ↓ | | 9 | 8 | 7 | 6 |
| | | | -7 | " | $V_2$ | | | | | | | 11 |
| | | | ↓ | 10 | ↓ | | | | | | | 12 |
| | | | | 18 | | | | | | | | 13 |
| | | | | 23 | | | | | | | | 14 |
| | | | | 28 | 0 | | | | | | | 15 |
| | | | | 37 | | | | | | | | 16 |
| | | | -11 | 0 | $V_2$ | | | | | | | 18 |
| | | | " | 23 | " | | | | | | | 19 |
| | | | -10 | 0/23 | $V_3$ | | | | | | | 21/22 |
| | | | -7 | 23 | 20 | | | | | | | 24 |
| | | | ↓ | " | 0 | | A | | | | | 25 |
| | | | | 0 | ↓ | | " | | | | | 26 |
| | | OIL FLOW | | 0/23 | | | 300 | | | | | 27 |
| | | | | " " | 15 | | ↓ | | | | | 28 |
| | | (VG REMOVED) | N/A | $\theta_1$ | — | | | | 29 | 30 | 31 | |
| | | | ↓ | $\theta_2$ | — | | 600 | | | | | 32 |
| | | | | 0/23 | — | | 400 | | | | | 33 |
| | | | | " | — | | 200 | | | | | 34 |

$\theta_1$ : 0, 10, 18, 23 $V_1$ : -10, -5, 0, 5 $V_3$ : -10, -5, 0, 5, 10, 15

$\theta_2$ : 0, 10, 18, 23, 28, 37 $V_2$ : 0, 5, 10, 15 A : 600, 400, 200

TABLE III

FLUCTUATING PRESSURE INSTRUMENTATION COORDINATES (OS-314)

| X \ Y | 14.62 | 12.0 | 6.0 | 0 | -6.0 | -12.0 |
|---|---|---|---|---|---|---|
| 5.0 | 1 | | | | | |
| 9.0 | 2 | | | | | |
| 13.0 | 3 | | | | | |
| 17.0 | 4 | | | | | |
| 21.0 | 5 | | | | | |
| 24.0 | | 8 | 11 | 14 | 17 | 20 |
| 25.0 | 6 | | | | | |
| 32.0 | | 9 | 12 | 15 | 18 | 21 |
| 33.0 | 7 | | | | | |
| 40.0 | | 10 | 13 | 16 | 19 | 22 |
| | | | CONTOUR SHELL | | | |
| 49.48 | | 101 | 106 | 114 | 122 | 130 |
| 51.99 | | | 107 | 115 | 123 | |
| 55.20 | | 102 | 108 | 116 | 124 | 131 |
| 58.69 | | | 109 | 117 | 125 | |
| 62.37 | | 103 | 110 | 118 | 126 | 132 |
| 66.19 | | | 111 | 119 | 127 | |
| 72.02 | | 104 | 112 | 120 | 128 | 133 |
| 77.92 | | 105 | 113 | 121 | 129 | 134 |

TABLE IVb TEST RUN SCHEDULE

DATE 6/3/83 TEST OS314 A ARC 9×7

| | CONFIGURATION | | VG | $\theta_{OMS}$ | $\delta_v$ | CONDITION | DYNAMIC PRESSURE | TIME | MACH NUMBERS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ID | Description | No. | Deg | Deg | | (PSF) | (Seconds) | | | | 2.5 |
| | H | BASELINE | N/A | 23 | – | ASCENT | 160→523→160 | ASAP | | | | 39 |
| | G | | " | | – | ENTRY | 160 | 156 | | | | 40 |
| | | | –7 | | 0 | | " | 250 | | | | 42 |
| | | | | | 15 | | 110 | | | | | 43 |
| | B | +T.C. | | | 0 | | 160 | | | | | 44 |
| | " | | | | 15 | | 110 | | | | | 45 |
| | F | T.C. + LUDOX COAT | | | 0 | ASCENT | 160→550→160 | ASAP | | | | 46 |
| | C | ½" GRID + T.C. | | | | | " " " | | | | | 47 |
| | D | ¼" GRID + T.C | | | | | " 545 " | | | | | 49 |
| | A | T.C. + RTV COAT | | | | | " 552 " | | | | | 50 |
| | | | | | 15 | ENTRY | 110 | 250 | | | | 51 |
| | | | | | 0 | ASCENT | 160→656→160 | ASAP | | | | 52 |
| | | | | | | ASC (LIFE) | 650 | 192 | | | | 53 |
| | | | | | | " " | " | 2166 | | | | 54 |
| | B | BASELINE + T.C. | | | 15 | ENTRY | 160 | 250 | | | | 58 |
| | J | OV99 (STS-6) | | | 0 | | " | | | | | 59 |
| | " | | | | 15 | | 110 | | | | | 60 |
| | 101 | ¼" GRID | | | 0 | ASCENT | 160→538→160 | ASAP | | | | 61 |
| | " | | | | 15 | ENTRY | 110 | 250 | | | | 62 |
| | | | | | | | | | | | | |

T.C.: THERMALLY CONDITIONED (1100 °F)

TABLE IVc TEST RUN SCHEDULE

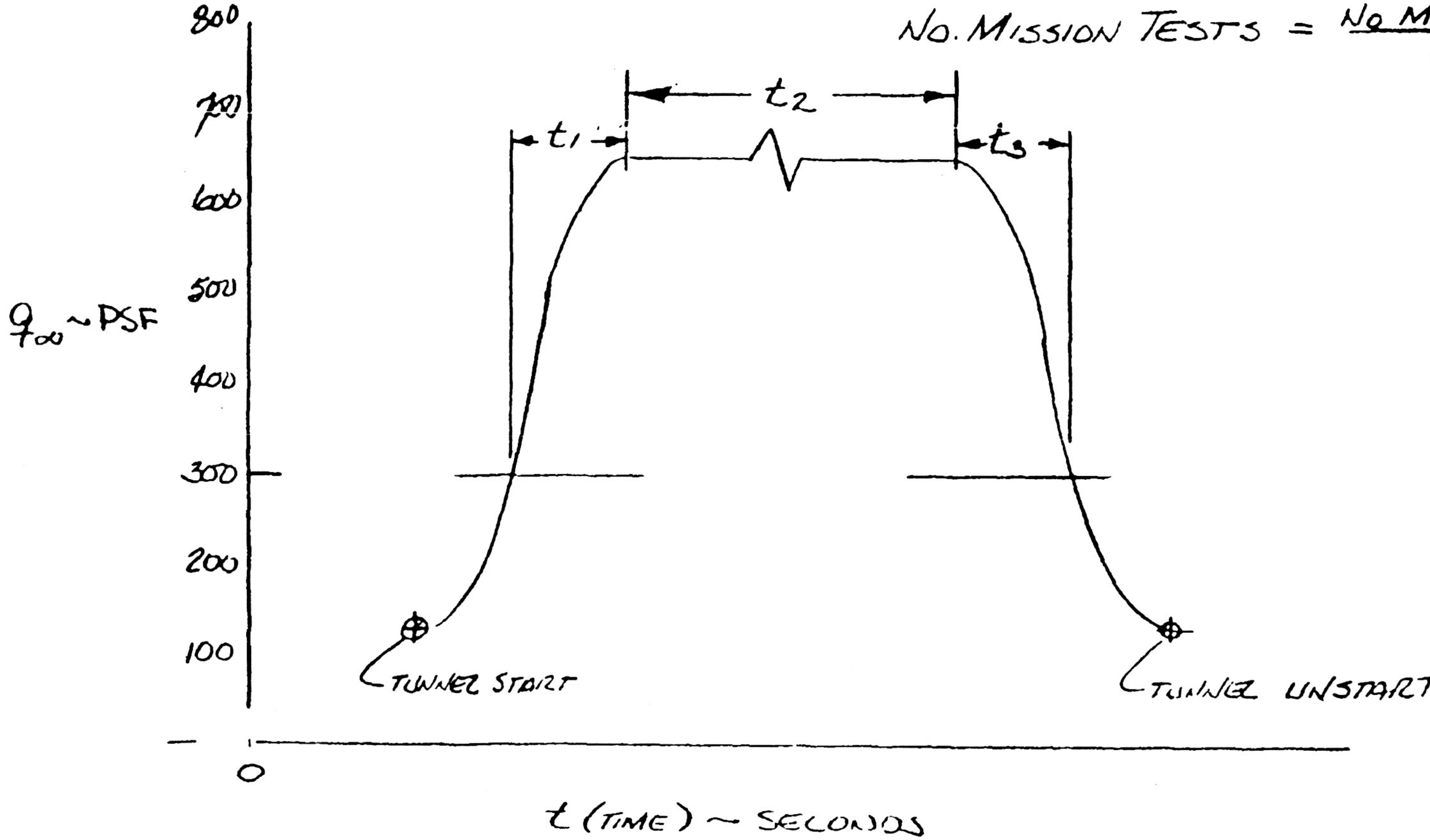
DATE 7/27/83 TEST OS314 B, C ARC 9×7

| | CONFIGURATION ID | Description | VG No. | $\theta_{OMS}$ Deg | $\delta_v$ Deg | CONDITION | DYNAMIC PRESSURE (PSF) | TIME (Seconds) | MACH NUMBERS | | | 2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | ¼" GRID FOR'D + T.C. | -7 | 23 | 0 | ASCENT | 160 → 657 → 160 | ASAP | | | | 101 |
| | " | | | | | ASC. (LIFE) | 650 | 74 | | | | 102 |
| | K | ½" GRID | | | | ASCENT | 160 → 670 | ASAP | | | | 103 |
| | M | OV99 (STS-6) | | | | ENTRY | 160 | 250 | | | | 104 |
| | | | | | 15 | " | 110 | 250 | | | | 105 |
| | O | JOINT FIXES | N/A | 23 | – | ASCENT | 160 → 640 → 160 | ASAP | | | | 201 |
| | N | REPAIR PATCHES | | | | " | " 651 " | " | | | | 202 |
| | I | BASELINE | | | | " | " 629 " | " | | | | 203 |
| | | | | | | ENTRY | 160 | 250 | | | | 203 |

TABLE V ASCENT MISSION LOADINGS

$$\text{No. MISSION LOADINGS} = \frac{t_1 + t_3}{50} + \frac{t_2}{8}$$

$$\text{No. MISSION TESTS} = \frac{\text{No. MISSION LOADING}}{4}$$




PYAO 7/15/83

## TABLE V ASCENT MISSION LOADINGS (CONTINUED)

(1) ASCENT PROFILE - ONE MISSION EXPOSURE

- VEHICLE DEVELOPS SHOCK SYSTEM AT $M_\infty \simeq 0.9$
- OMS POD L.E. CAUSES SHOCK SYSTEM TO REMAIN THROUGH THE SUPERSONIC FLIGHT
- AERO ACOUSTIC AND AERO LOADS ASSUMED TO BE NON-DESTRUCTIVE AT $Q_\infty < 375$ PSF

STS-6 FLIGHT

- $M_\infty = 0.9$ @ $\tau = 45$ SEC FROM LIFT-OFF
- $Q = 375, M_\infty = 2.75$ @ $\tau = 90$ SEC FROM LIFT-OFF

ONE ASCENT FLIGHT LOADING $\approx$ 50 SEC

WIND TUNNEL

- AT $M = 2.5$, SHOCK SYSTEM DEVELOPED AT ALL Q's
- $Q \approx 300$ PSF IS EQUIVALENT LOAD TO FLIGHT $Q = 375$ PSF
  $\therefore$ FOR WIND TUNNEL TEST PROFILE $\tau$ (ABOVE $Q = 300$ PSF)/50 SEC
  = NUMBER ASCENT MISSIONS

## TABLE V ASCENT MISSION LOADINGS (CONTINUED)

(2) ACCUMULATED ASCENT MISSIONS AT MAXIMUM Q

MISSIONS IN THE OMS POD AREA ARE ACCUMULATED @ ~32 SEC/MISSION (SCATTER FACTOR OF 4 ON ACOUSTIC LOADING)

(3) TO ACCUMULATE NUMBER OF MISSION LOADINGS ON A SAMPLE OF AFRSI IN THE OMS POD AREA IN THE WIND TUNNEL, THE FOLLOWING APPLIES:

1. ASCENT EXCURSION - Q = 300 PSF TO MAX ($T_1$) TO 300 PSF ($T_3$)
   NUMBER ASCENT MISSIONS = $(T_1 + T_3)/50$ SEC
2. ASCENT MISSIONS ACCUMULATED AT MAX WIND TUNNEL Q
   NUMBER ASCENT MISSIONS: TIME @ MAX Q ($T_2$)/8 SEC

$$\text{TOTAL MISSION LOADINGS/RUN} = \frac{(T_1 + T_3)}{50\ \text{SEC}} + \frac{T_2}{8\ \text{SEC}}$$

(4) TO QUALIFY FOR CEI SPEC MATERIAL FATIGUE TEST*:

ACCUMULATED MISSIONS = TOTAL MISSION LOADING/4

*FATIGUE TEST REQUIREMENTS IN CEI SPEC., REF. MIL-A-8866, "AIRPLANE STRENGTH RIDIGITY RELIABILITY REQUIREMENTS, REPEATED LOADS AND FATIGUE"

## TABLE V ASCENT MISSION LOADINGS (CONCLUDED)

SCATTER FACTOR OF 4
"ECONOMICAL FATIGUE TESTING"

- NORMALLY MATERIAL FATIGUE TESTS ARE ACCOMPLISHED WITH MANY SAMPLES, E.G., 20 TO 100 UNDER LIKE LOADING CONDITIONS
- FAILURE DATA IS COLLECTED AND VARIATIONS IN FAILURE STATISTICALLY ANALYZED
- THE NASA REQUESTED THAT A SCATTER FACTOR OF 4 BE APPLIED TO LOADINGS OF ONE MATERIAL SAMPLE FOR FATIGUE TESTING PROCEDURE - ACCEPTED BY AIR FORCE AS ECONOMICAL METHOD FOR TESTS; REFERENCE MIL SPEC NUMBER MIL-A-8866

TABLE VI SUMMARY OF RESULTS



| TEST ARTICLE | ENVIRONMENT | REMARKS |
|---|---|---|
| H-BASELINE | STS-6 ASCENT (700 SEC) | FAILURE BEGAN APPROX. $q$=400 $T \approx 200$ SEC.<br>FAILURE OBVIOUS @ $q$=525<br>FAILURE STARTED ~1½ INCHES AFT OF MATERIAL L.E. (2 PATCHES GONE ≈10x10-INCH R.H. SIDE & 5x7-INCH L.H. SIDE) |
| G-BASELINE | ENTRY (156 SEC) | OK |
| G-BASELINE | ENTRY - VG @ 0° (250 SEC) | OK |
| G-BASELINE | ENTRY - VG @ 15° (250 SEC) | OK |
| B-BASELINE (1100°F TEMP) | ENTRY - VG @ 0° (250 SEC) | OK |
| B-BASELINE (1100°F TEMP) | ENTRY - VG @ 15° (250 SEC) | OK |

## TABLE VI SUMMARY OF RESULTS (CONTINUED)

OS-314A

| TEST ARTICLE | ENVIRONMENT | REMARKS | |
|---|---|---|---|
| F-BASELINE + LUDOX + REWATER PROOF (1100°F) | STS-6 ASCENT (550 SEC) | FAILURE BEGAN AT 550 q, T≃325 SEC. THREAD FAILURE STARTED SAME LOCATION - SPREAD TO APPROX. 4½ INCHES DIA. - MIGRATED Q-FELT, OUTER FABRIC NOT DESTROYED, LUMP OUTER ML. | |
| C-1/2 INCH STITCH PATTERN (1100°F) | STS-6 ASCENT (550 SEC) | MINOR FAILURE (~2 INCH DIA THREAD BREAK & SURFACE MATERIAL BREAKING) FAILURE BEGAN SAME TIME & Q AS (F T/A) | |
| D-1/4 INCH STITCH PATTERN (1100°F) | STS-6 ASCENT (678 SEC) | BEGAN TO LOSE LONGITUDINAL THREADS AT MAX Q (545 PSF). L.H. CORNER 1½ INCHES BACK POUCHED ~1 INCH DIA AFTER 408 SEC ON DOWN SIDE OF PROFILE. R.H. CORNER FORWARD FRAYED (MINOR DAMAGE) | |
| A-BASELINE W/ 92007 RTV ON OML + REWATERPROOF (800°F) | STS-6 ASCENT | AT MAX Q, FLUTTER OF ROW 2 INCHES BACK, SOFTENING OF MATERIAL AT 2 INCHES AFT EACH SIDE | |
| | ENTRY - VG @ 15 | NO CHANGE | |
| | ASCENT DESIGN | NO CHANGE | ACCUM 11.7 ASCENT MISS. |
| | ASCENT + 192 SEC HOLD | NO CHANGE | TO ACCUM 25 ASCENT MISS. |
| | ASCENT + 25 MIN HOLD | PROGRESSIVE THREAD LOSS AROUND L&R SIDE | ACCUM 80 ASCENT MISS. |

SPACE SHUTTLE ORBITER

TABLE VI SUMMARY OF RESULTS (CONTINUED)

OS-314A

| TEST ARTICLE | ENVIRONMENT | REMARKS |
| --- | --- | --- |
| B-BASELINE (1100°F) | ENTRY - VG @ 15° (250 SEC) | OK (3RD ENTRY SIM. - W/VORTEX @ q=160 PSF) |
| J-OV-099 BLANKET | ENTRY - VG @ 0° (250 SEC) | OK |
| J-OV-099 BLANKET | ENTRY - VG @ 15° (250 SEC) | OK |
| 101 - 1/4 INCH STITCHING | STS-6 ASCENT | L.E. GAPPED ~1/8 INCH @ q=160 |
| | ENTRY - VG @ 15° (250 SEC) | L.E. FRAYING AROUND GAP |

SPACE SHUTTLE ORBITER

TABLE VI SUMMARY OF RESULTS (CONTINUED)

OS-314B

| TEST ARTICLE | ENVIRONMENT | REMARKS |
|---|---|---|
| L - 1/4 INCH STITCH GRID ON FIRST 12 INCHES FROM LE, THEN 1/2 INCH STITCH | 1. DESIGN ASCENT (733 SEC) | 430 SEC ABOVE 300 q, = 8.6 MISSIONS, BROKEN STITCHES, MINOR FRAYING IN 1/4 INCH STITCH AREA NEAR LE |
| | 2. DESIGN ASCENT (74 SEC HOLD) | 337 SEC ABOVE 300 q, 74 SEC AT 650 q, = 14.5 MISSIONS - PUFFING, THREAD DAMAGE, FACE COVERING BROKEN, Q-FELT LOST |
| K - 1/2 INCH STITCH HEAVY FACE COVER (0.060 INCH) | DESIGN ASCENT | THREADS BROKEN AT 425 q - LOST Q-FELT AT 600 q - CATASTROPHIC FAILURE AT 660 q FAILURE BEGAN AT 60 SEC ABOVE 300 q, = 3 MISSIONS |
| M = OV-099 BLANKET | 1. ENTRY W/O VG (250 SEC) | LOOSE THREADS BEFORE TEST - 5 BROKEN THREADS AFTER TEST |
| | 2. ENTRY VG @ 15° (250 SEC) | NO FURTHER DAMAGE |

SPACE SHUTTLE ORBITER

## TABLE VI SUMMARY OF RESULTS (CONCLUDED)

OS-314C

| TEST ARTICLE | ENVIRONMENT | REMARKS |
|---|---|---|
| O - JOINT FIXES | DESIGN ASCENT (810 SEC) | BROKEN STITCHES @ q=560 - GAPS OPENED 1/2 INCH |
| N - FACE SHEET REPAIRS | DESIGN ASCENT (820 SEC) | RHS FORWARD FACE SHEET FAILED @ q=440 - RTV COATED SHEET (LHS) SUFFERED NO DAMAGE |
| I - BASELINE | INCREASE q TILL DAMAGE OBSERVED - RETRACT MODEL AND DECREASE q TO 160 - REINSERT MODEL AND MAINTAIN q FOR 250 SEC | BROKEN THREADS, PUFFINESS, SURFACE DEGRADATION @ q=560 - ONLY MINOR ADDITIONAL DAMAGE @ LOW q - OML COVER REMAINED INTACT |

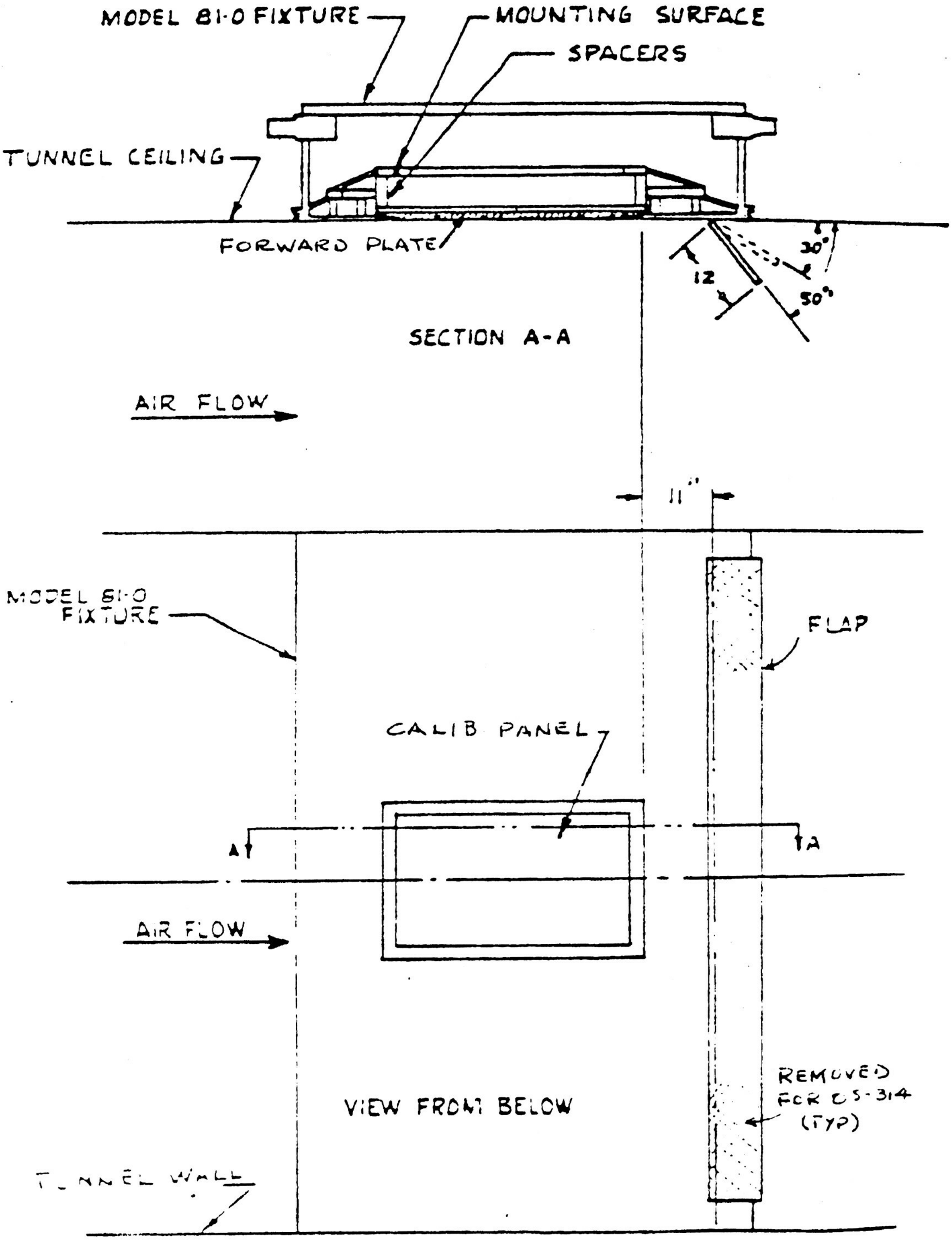



FIGURE 1. MODEL 81-Ø TEST FIXTURE, GENERAL ARRANGEMENT (OS-314)

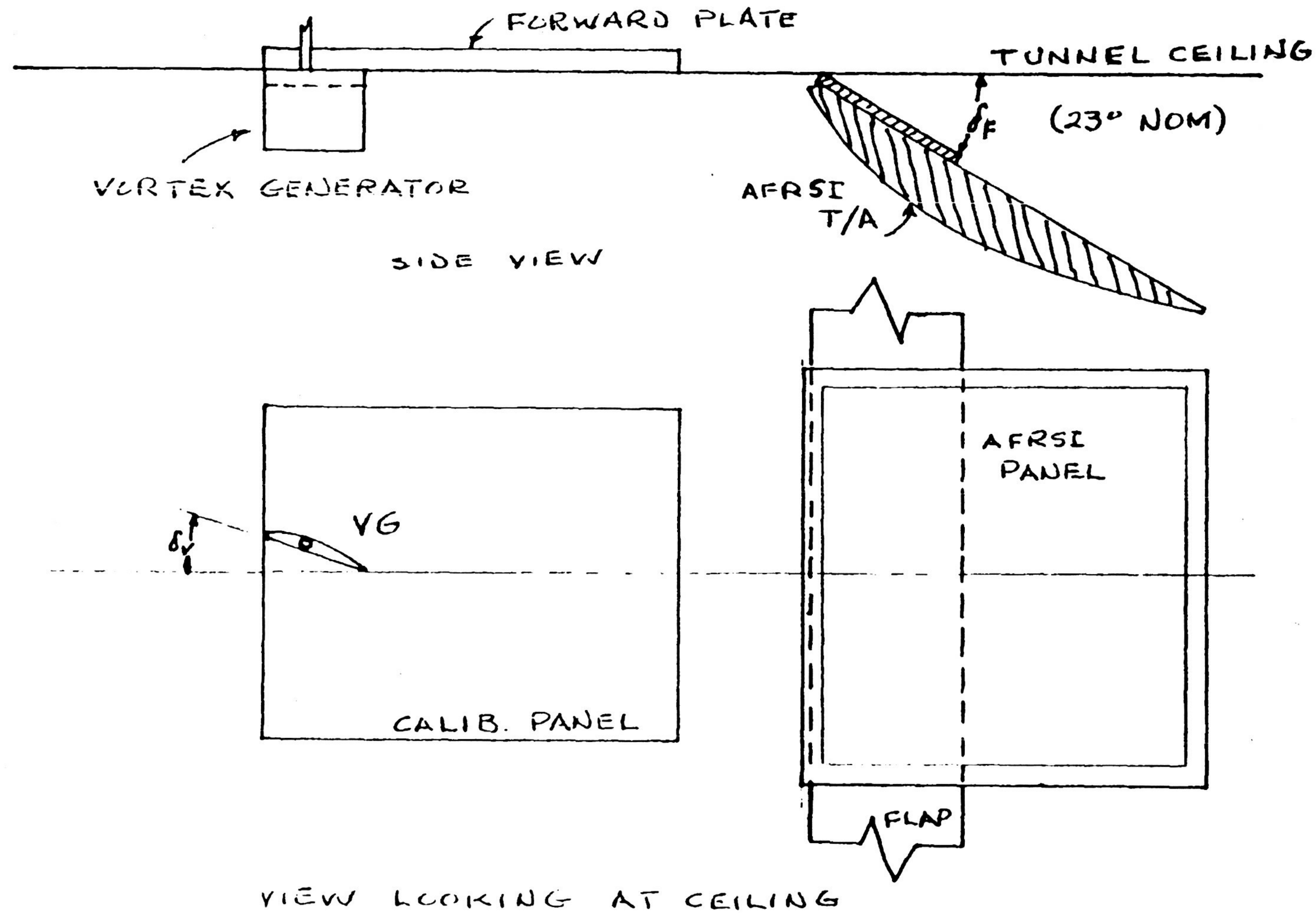
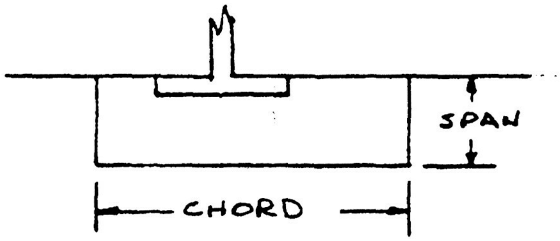
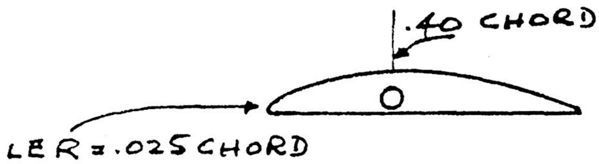



FIGURE 2. TEST INSTALLATION SCHEMATIC (OS-314)




CONFIGURATIONS

| VG | SPAN | CHORD |
|---|---|---|
| -4 * | 2.5 in | 4.5 in |
| -5 * | 2.5 | 7.0 |
| -6 * | 2.5 | 14.0 |
| -7 WEDGE | 3.5 | 14.0 |
| -8 * | 5.0 | 9.0 |
| -9 * | 5.0 | 14.0 |
| -10 * | 7.0 | 7.0 |
| -11 * | 7.0 | 13.0 |

* CAMBERED AIRFOIL

FIGURE 3. VORTEX GENERATORS SCHEMATIC (OS-314)

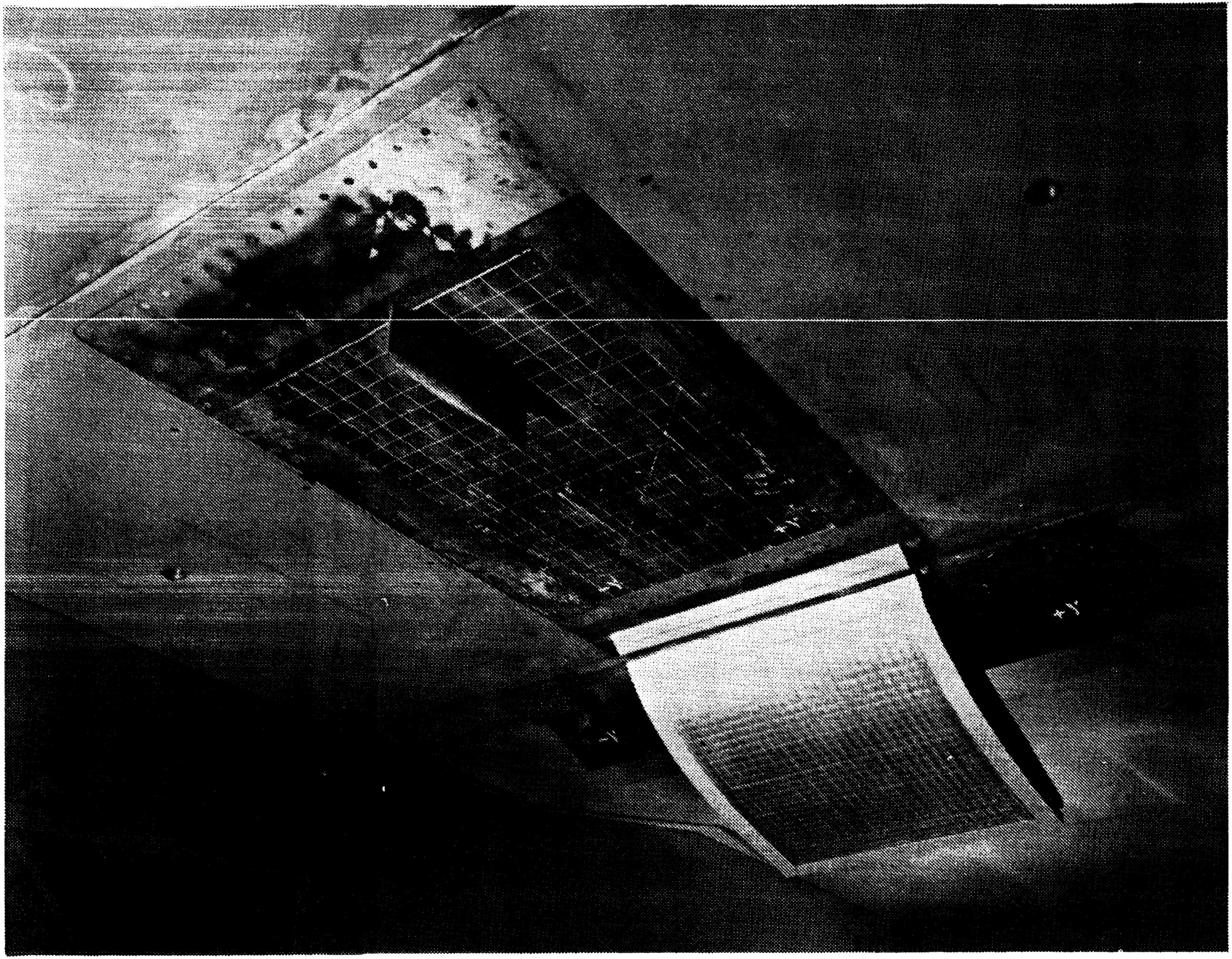
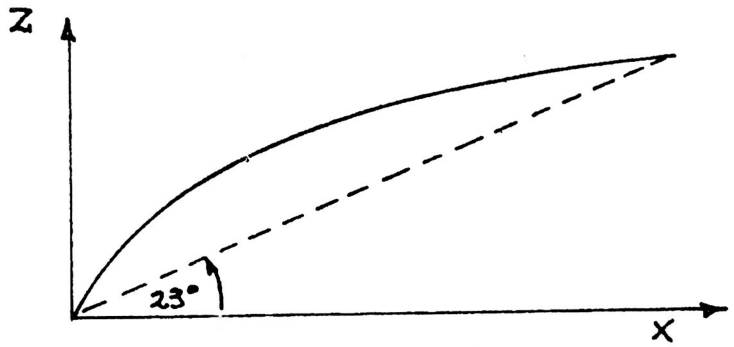


FIGURE 4. Model/Specimen Installation




Polynomial Approximation:

$$Z = A_0 + A_1X + A_2X^2 + A_3X^3 + A_4X^4 + A_5X^5 + A_6X^6 + A_7X^7$$

where $A_0$ = 6.7072E-02    $A_4$ = -2.8881E-03

$A_1$ = 2.2588E+00    $A_5$ = 1.1687E-04

$A_2$ = -3.4346E-02    $A_6$ = -2.4734E-06

$A_3$ = 4.0529E-02    $A_7$ = 2.1238E-08

for $\theta_{OMS}$ = 23 degrees

Coordinates:

| X, in. | Z, in. | X, in. | Z, in. |
|---|---|---|---|
| 0.000 | 0.0000 | 3.3440 | 4.9560 |
| 0.1625 | 0.4375 | 4.2195 | 5.7275 |
| 0.3985 | 0.9290 | 4.8935 | 6.2685 |
| 0.6245 | 1.3420 | 6.0490 | 7.1045 |
| 0.8850 | 1.8635 | 7.0815 | 7.7975 |
| 1.1410 | 2.2960 | 8.4735 | 8.5940 |
| 1.4215 | 2.7140 | 9.9830 | 9.3710 |
| 1.7215 | 3.1465 | 12.0340 | 10.3100 |
| 2.0215 | 3.5250 | 15.0390 | 11.4555 |
| 2.3655 | 3.9330 | 18.5700 | 12.5320 |
| 2.6950 | 4.2970 | 22.8335 | 13.5940 |
| 3.0295 | 4.6410 | 27.2645 | 14.5480 |
| | | 29.9445 | 15.0295 |

FIGURE 5. OMS POD MODEL CONTOUR SHAPE

1/3-SCALE NOMINAL ANGLE

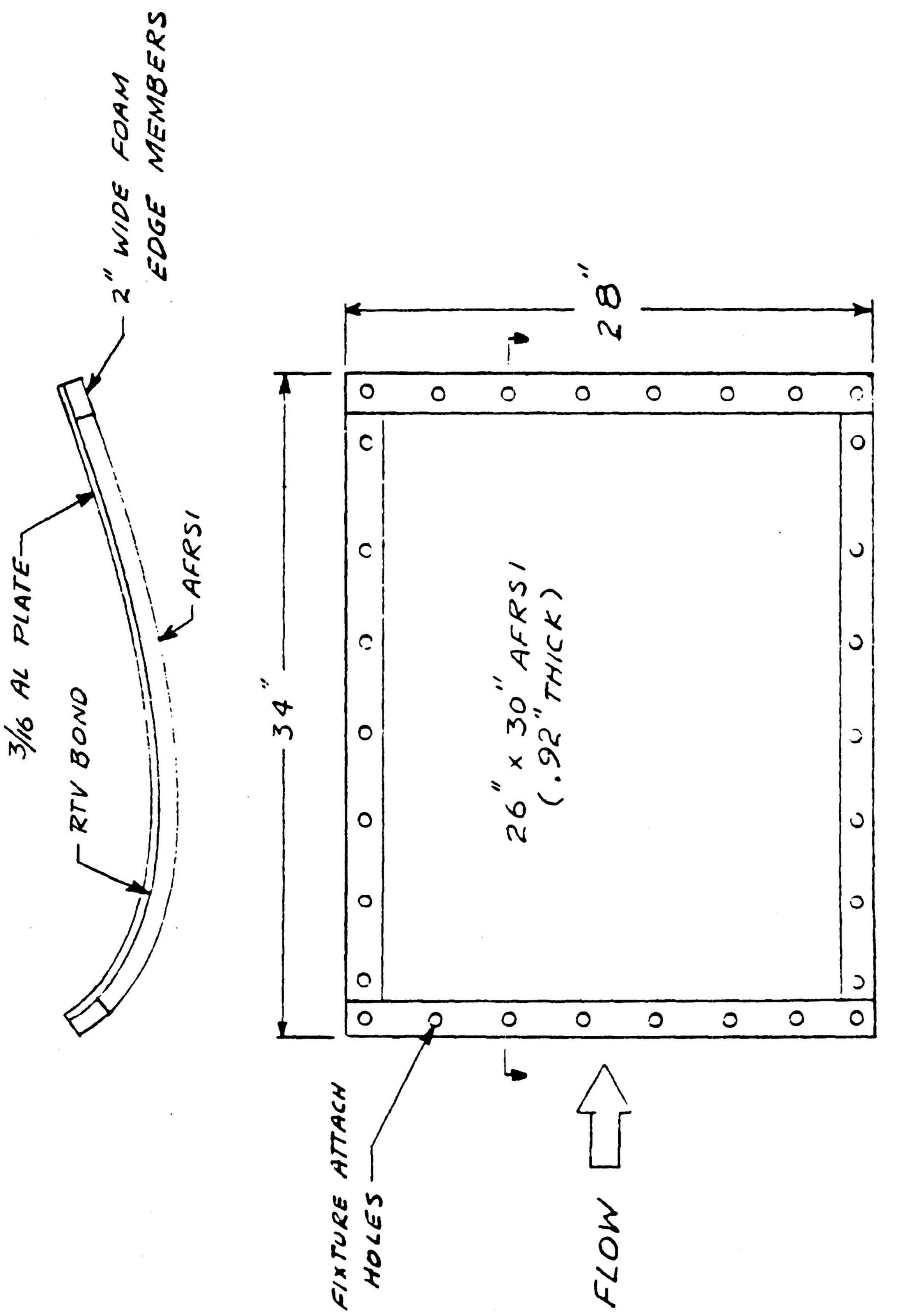



FIGURE 6. TEST ARTICLE CONFIGURATION

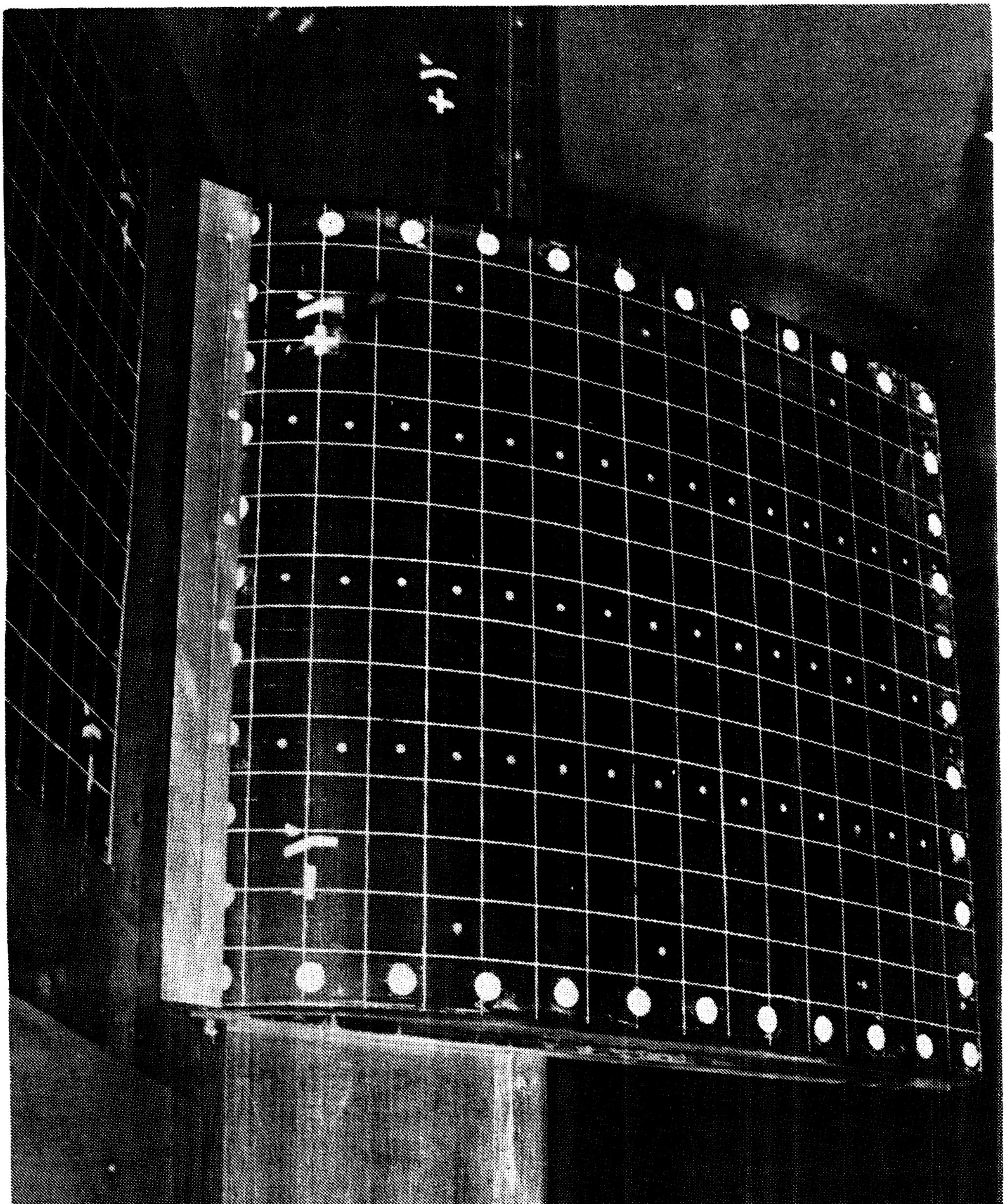


FIGURE 7. Pressure Calibration Panel (Fully Deflected)

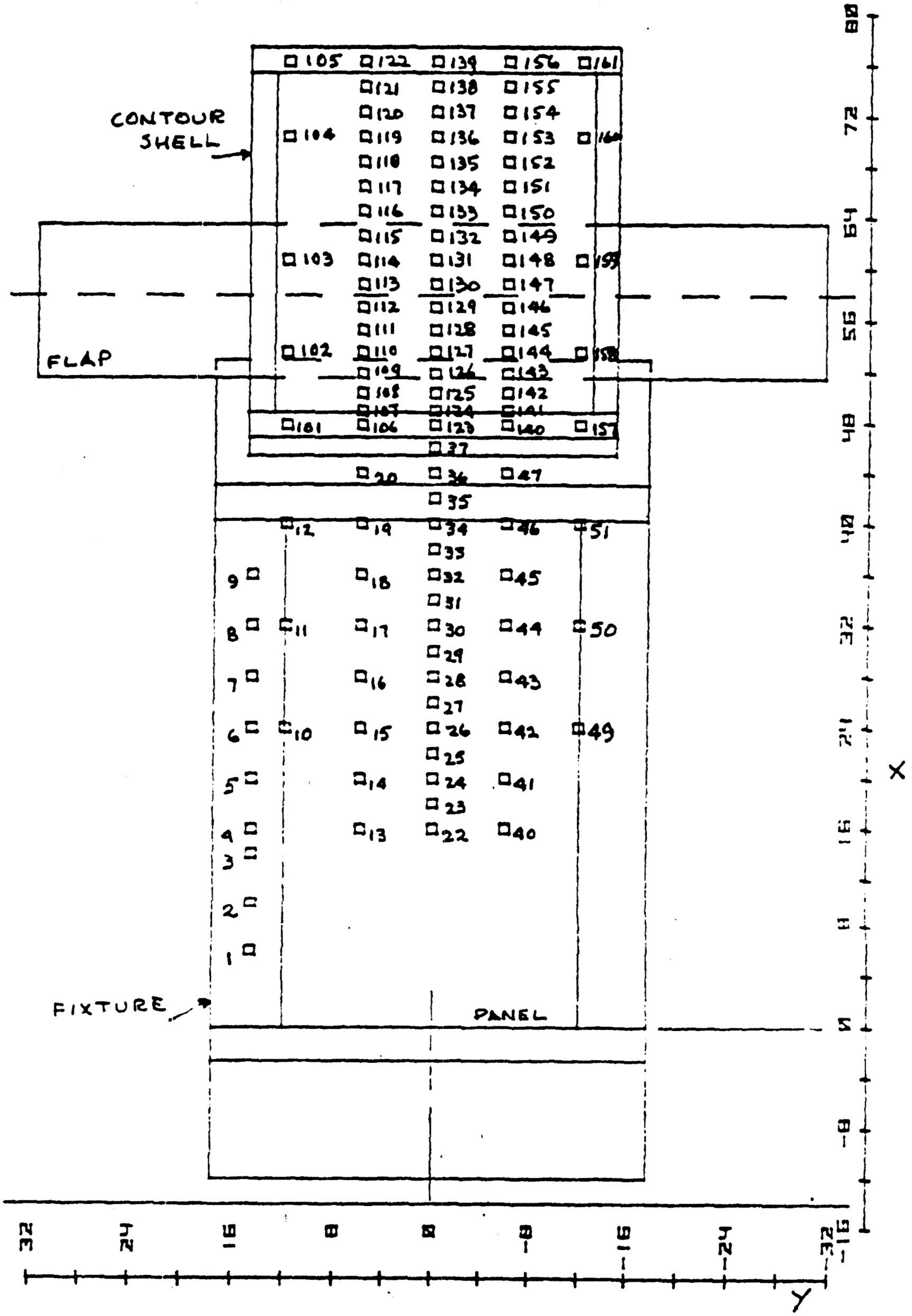



FIGURE 8. STATIC PRESSURE INSTRUMENTATION LAYOUT (OS-314)

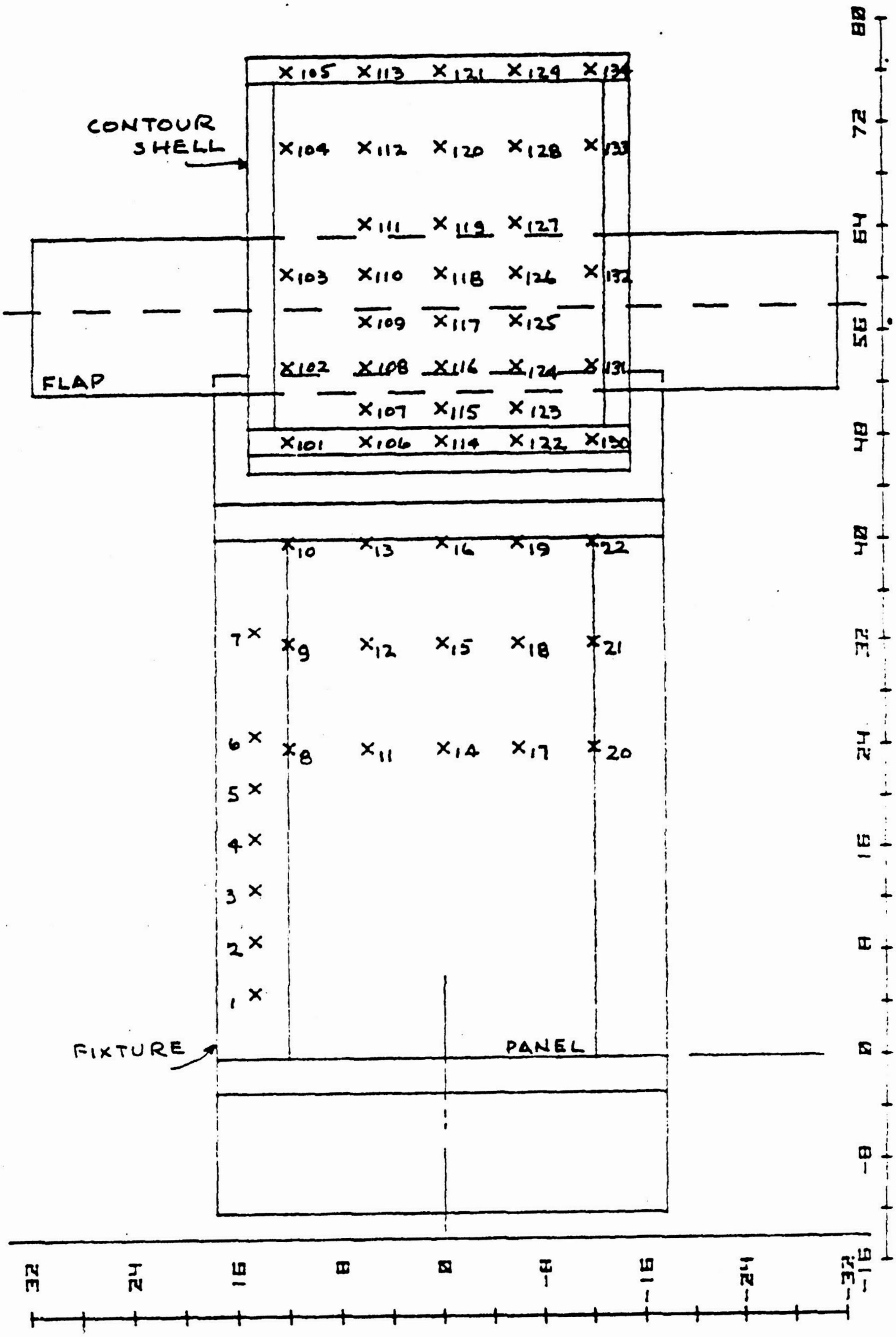



FIGURE 9. FLUCTUATING PRESSURE INSTRUMENTATION LAYOUT (OS-314)

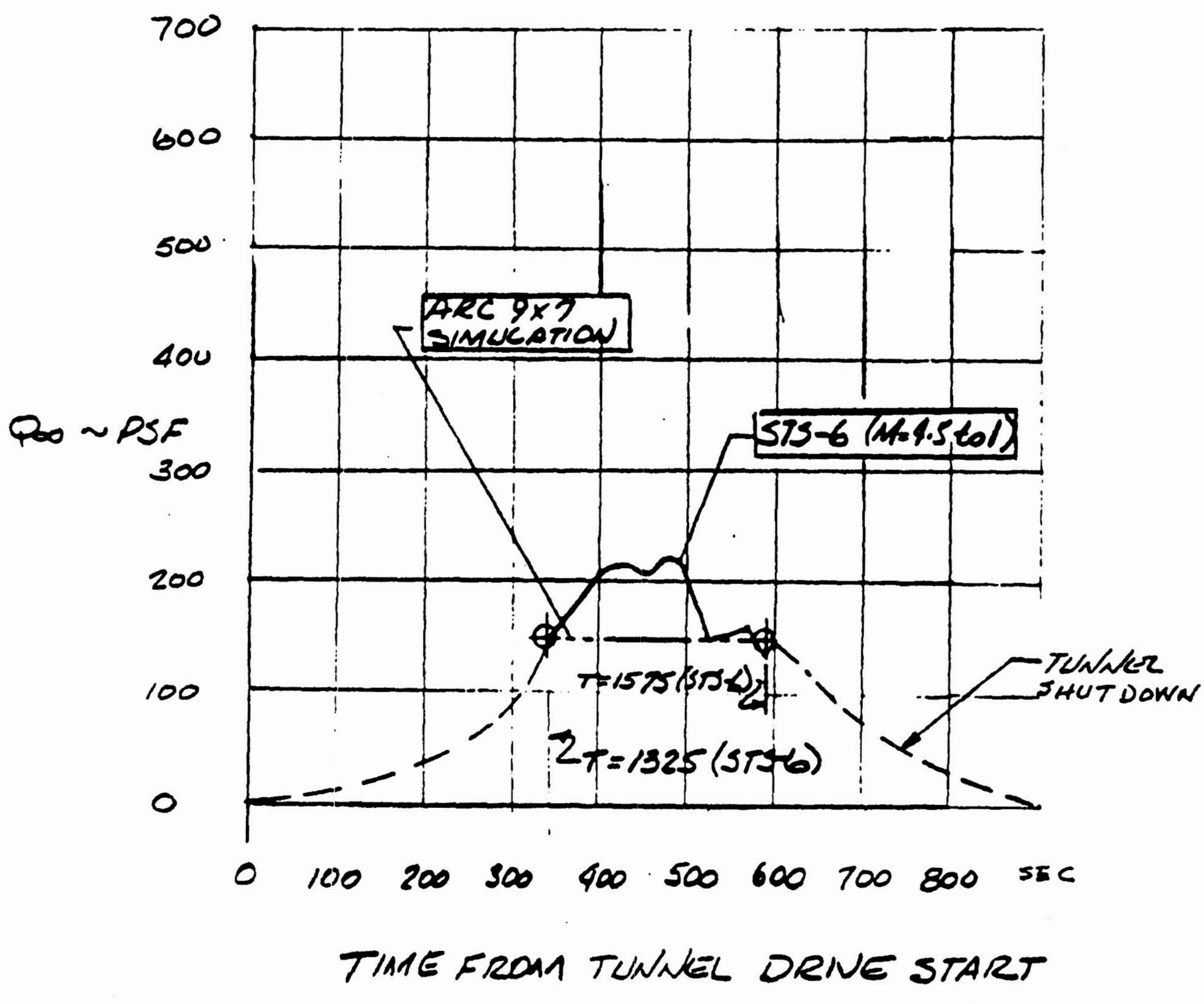



FIGURE 10. DYNAMIC PRESSURE PROFILE - ENTRY

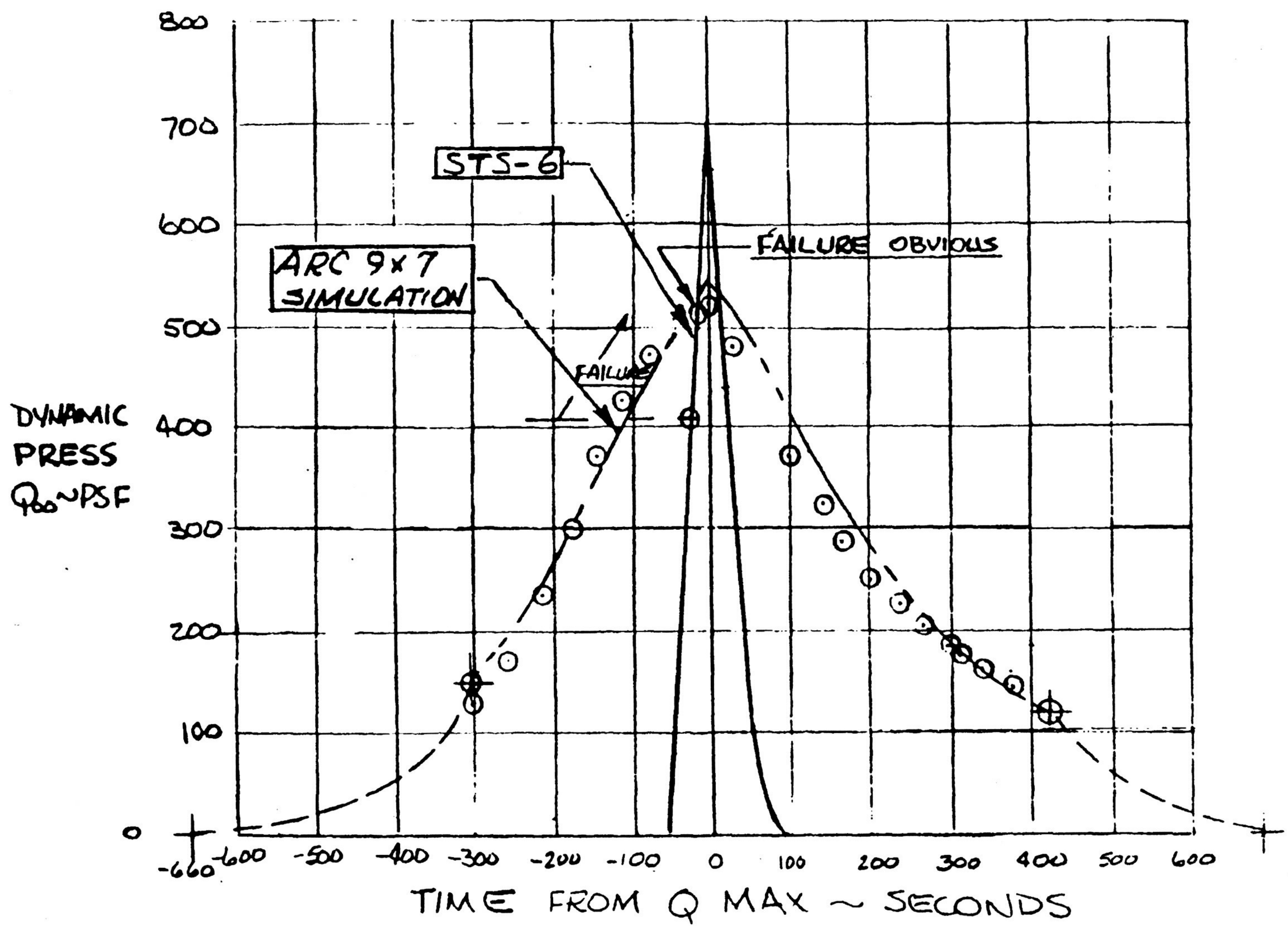



FIGURE 11. DYNAMIC PRESSURE PROFILE - ASCENT

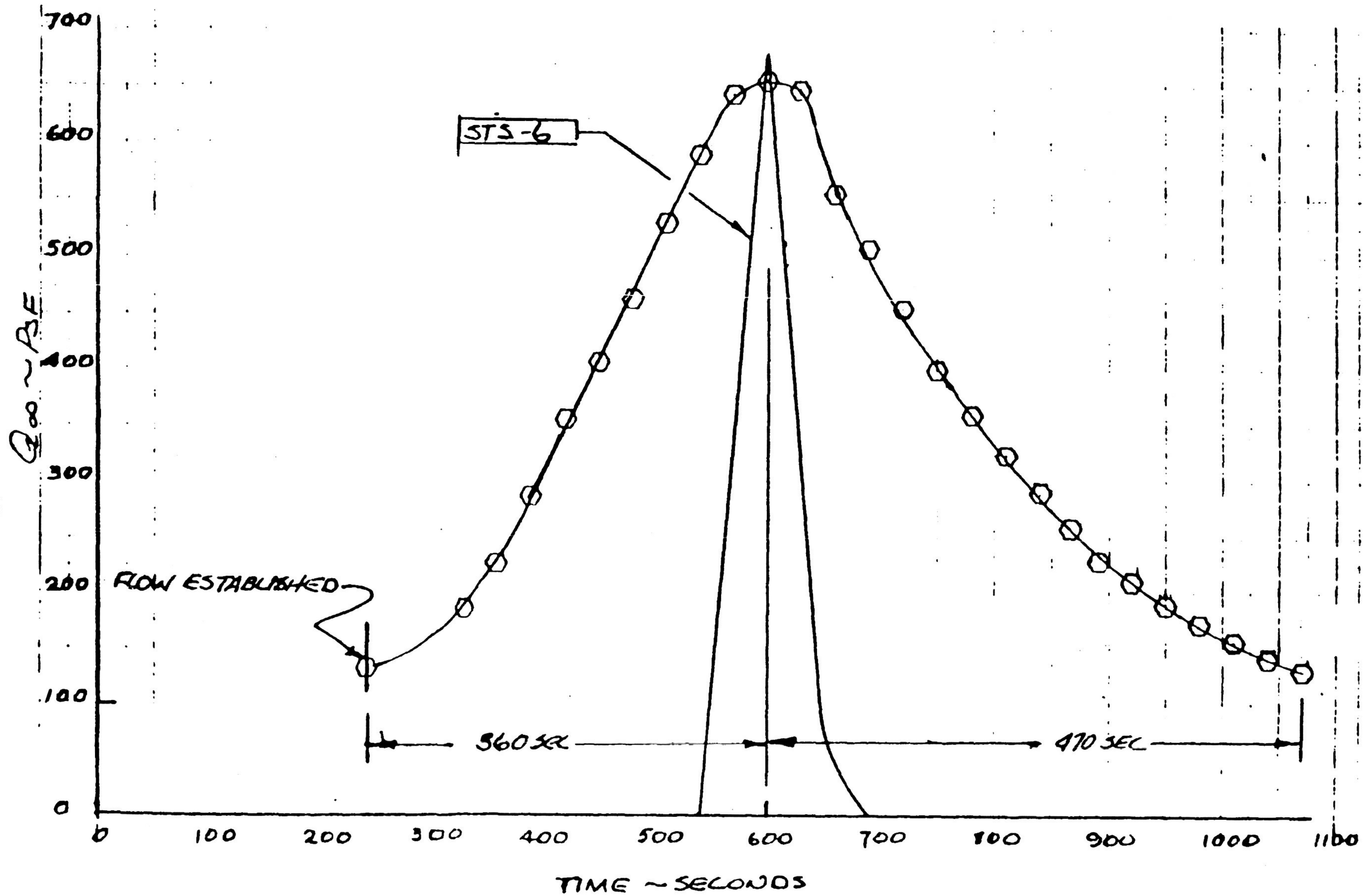



FIGURE 12. DYNAMIC PRESSURE PROFILE - DESIGN ASCENT

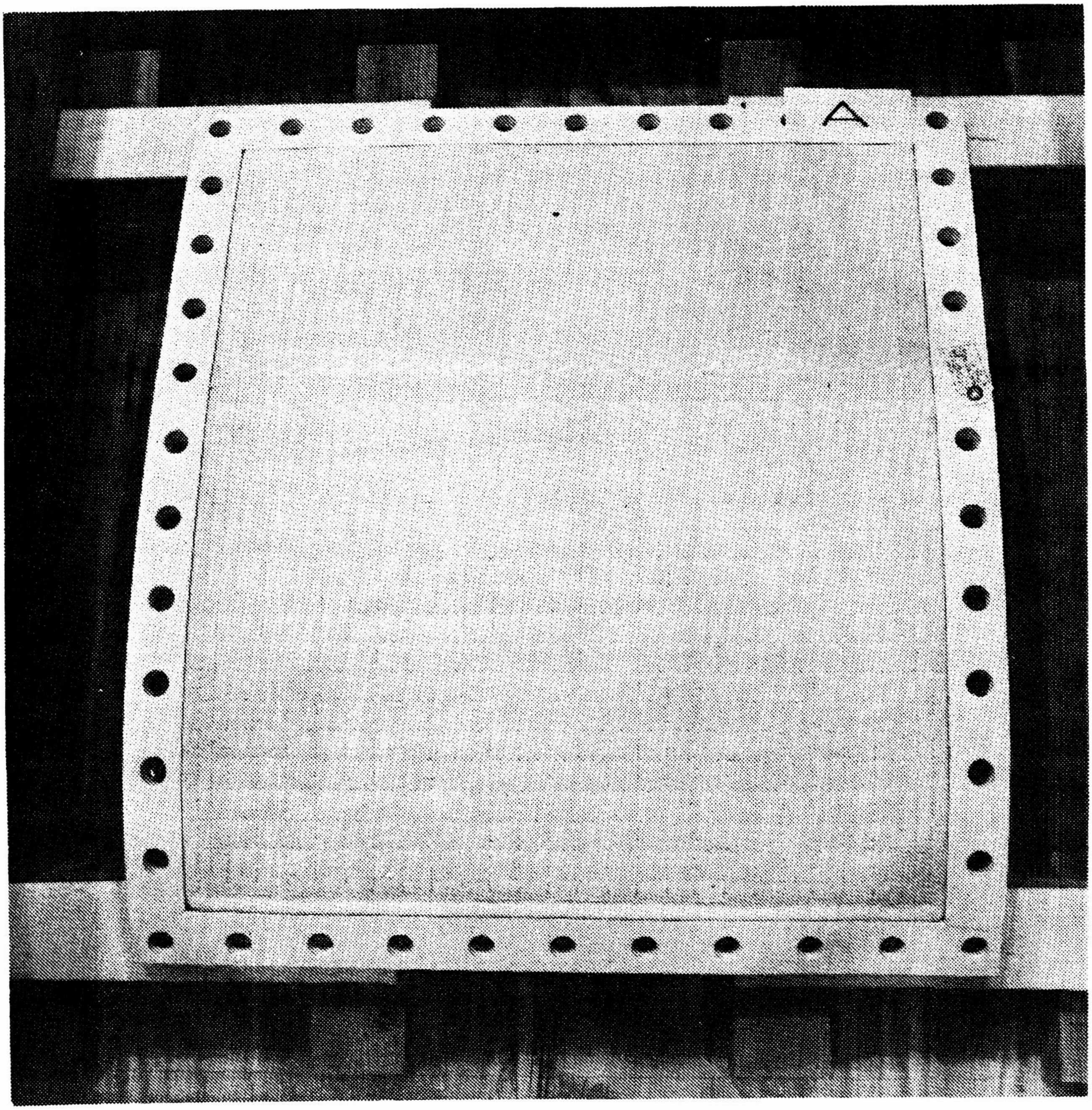



FIGURE 13a. Configuration A - Pre-Test

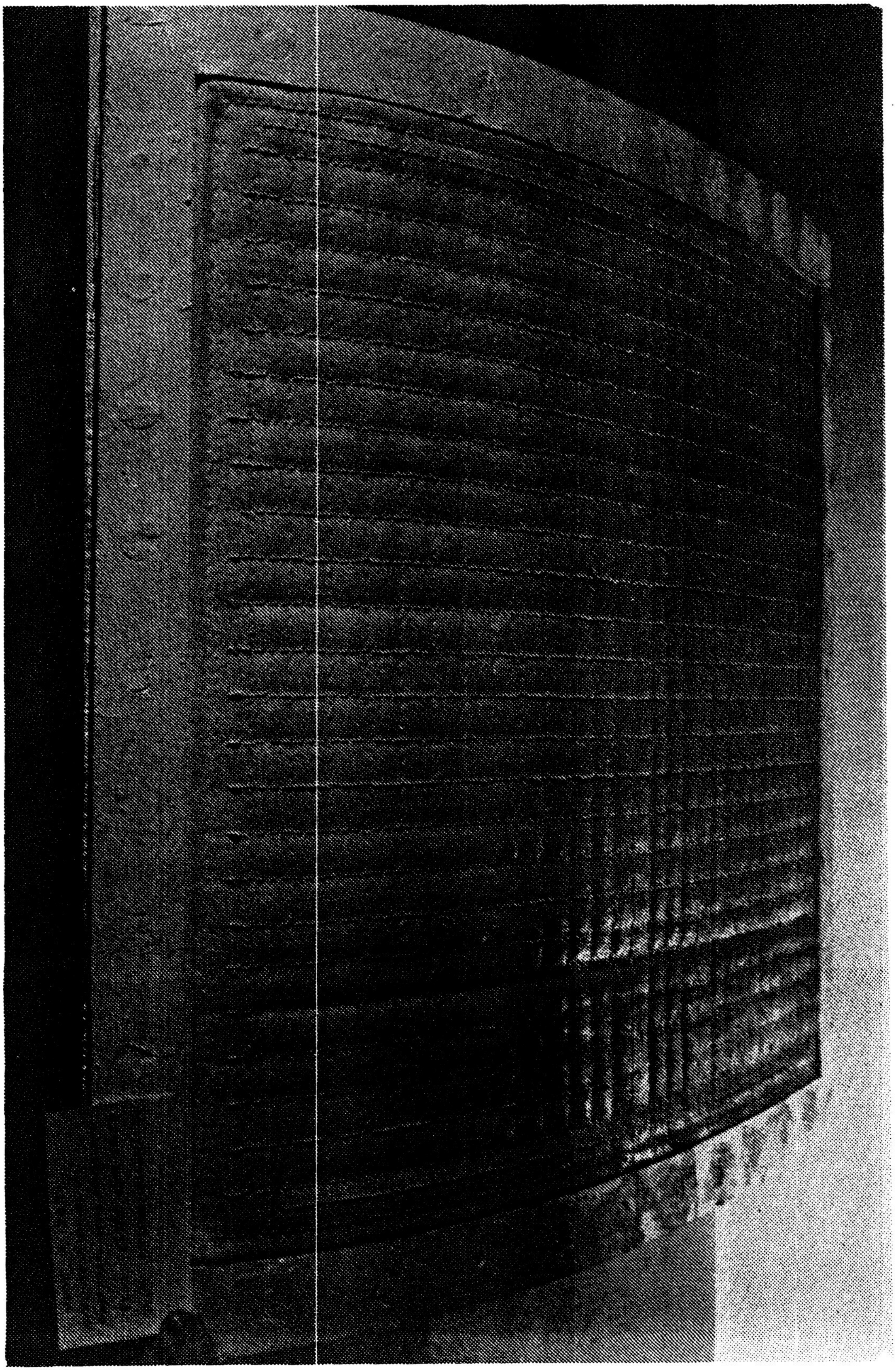


FIGURE 13b. Configuration A - Post-Test

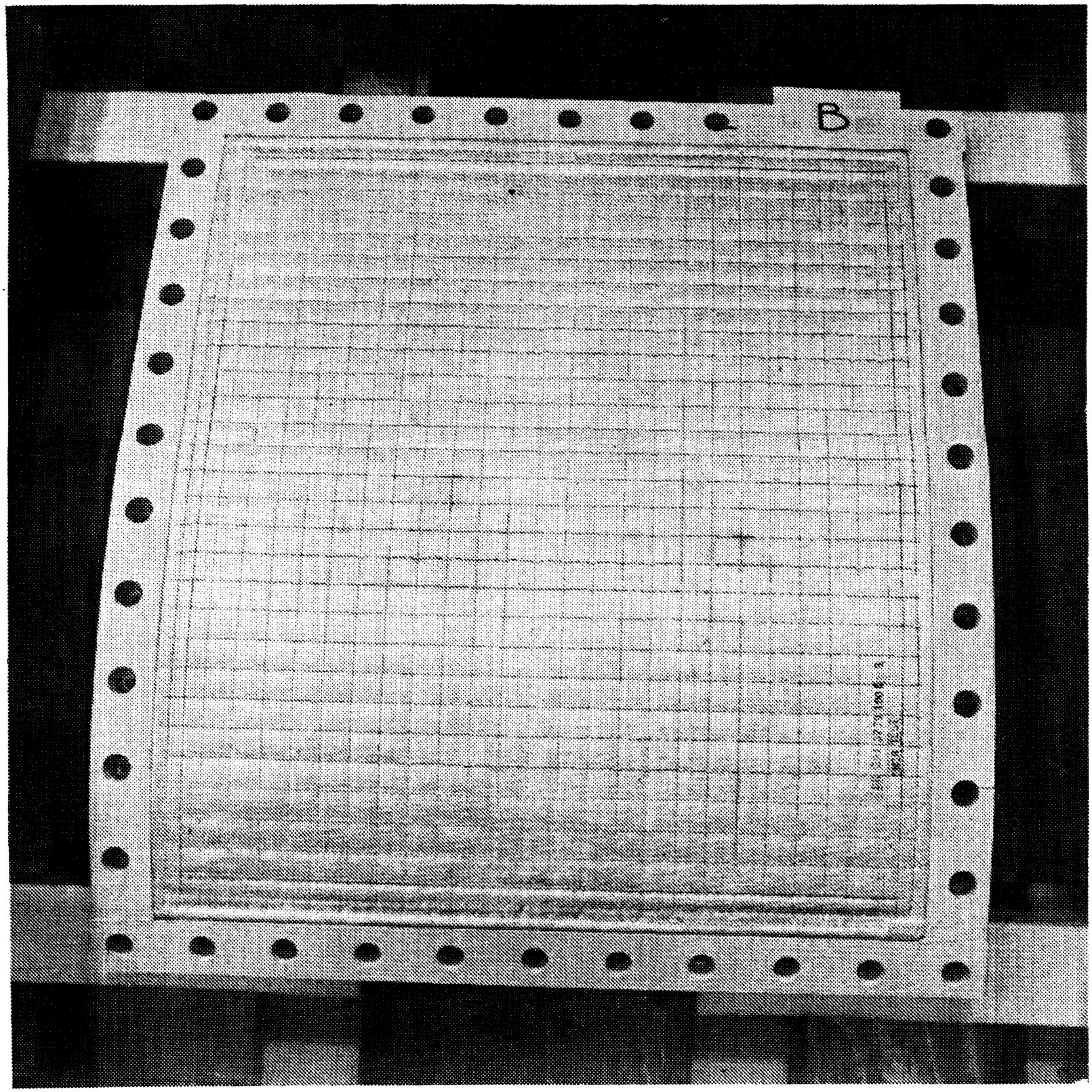



FIGURE 13c. Configuration B - Pre-Test

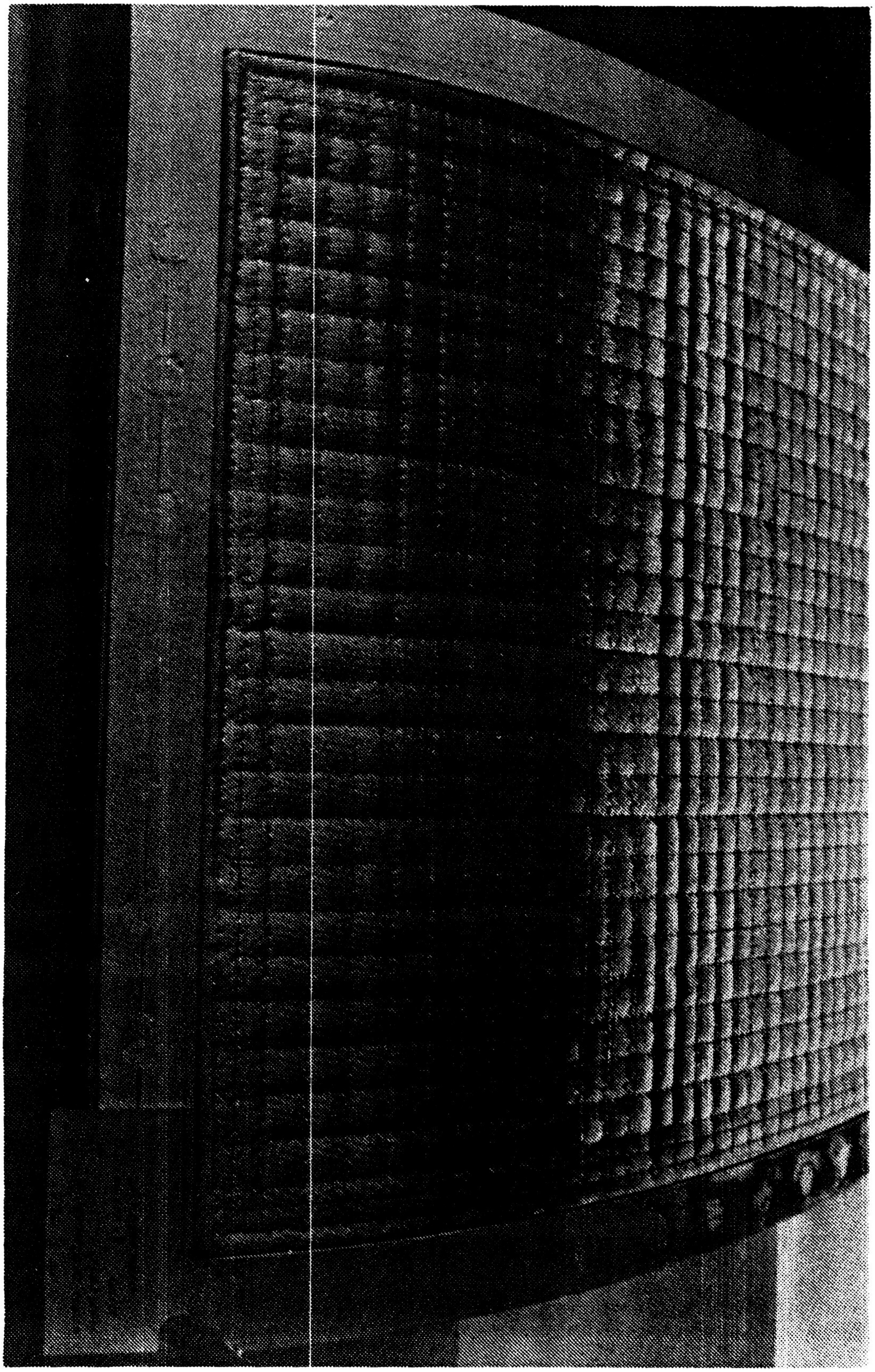


FIGURE 13d. Configuration B - Post Test

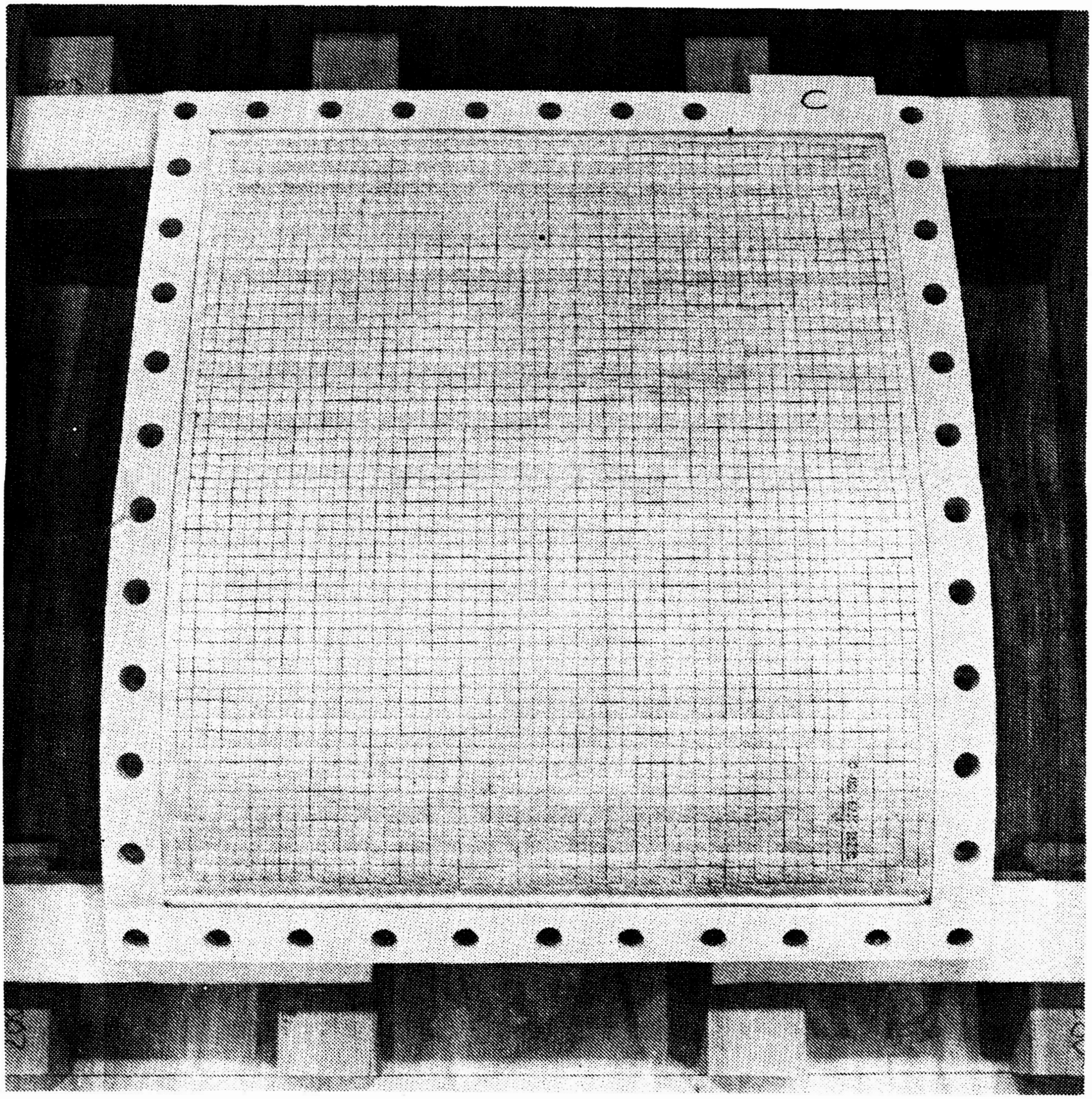



FIGURE 13e. Configuration C - Pre-Test

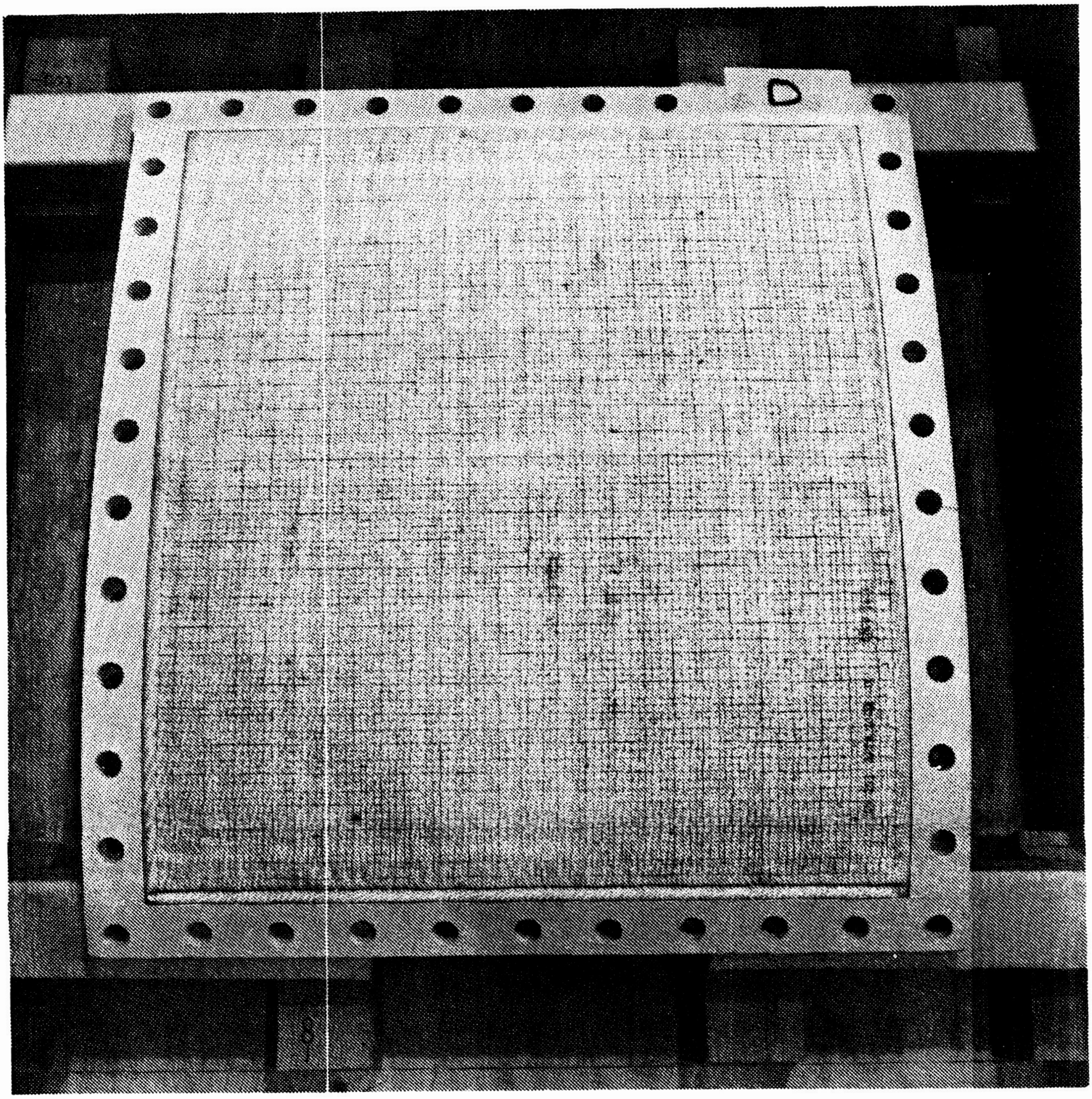


FIGURE 13f. Configuration D - Pre-Test

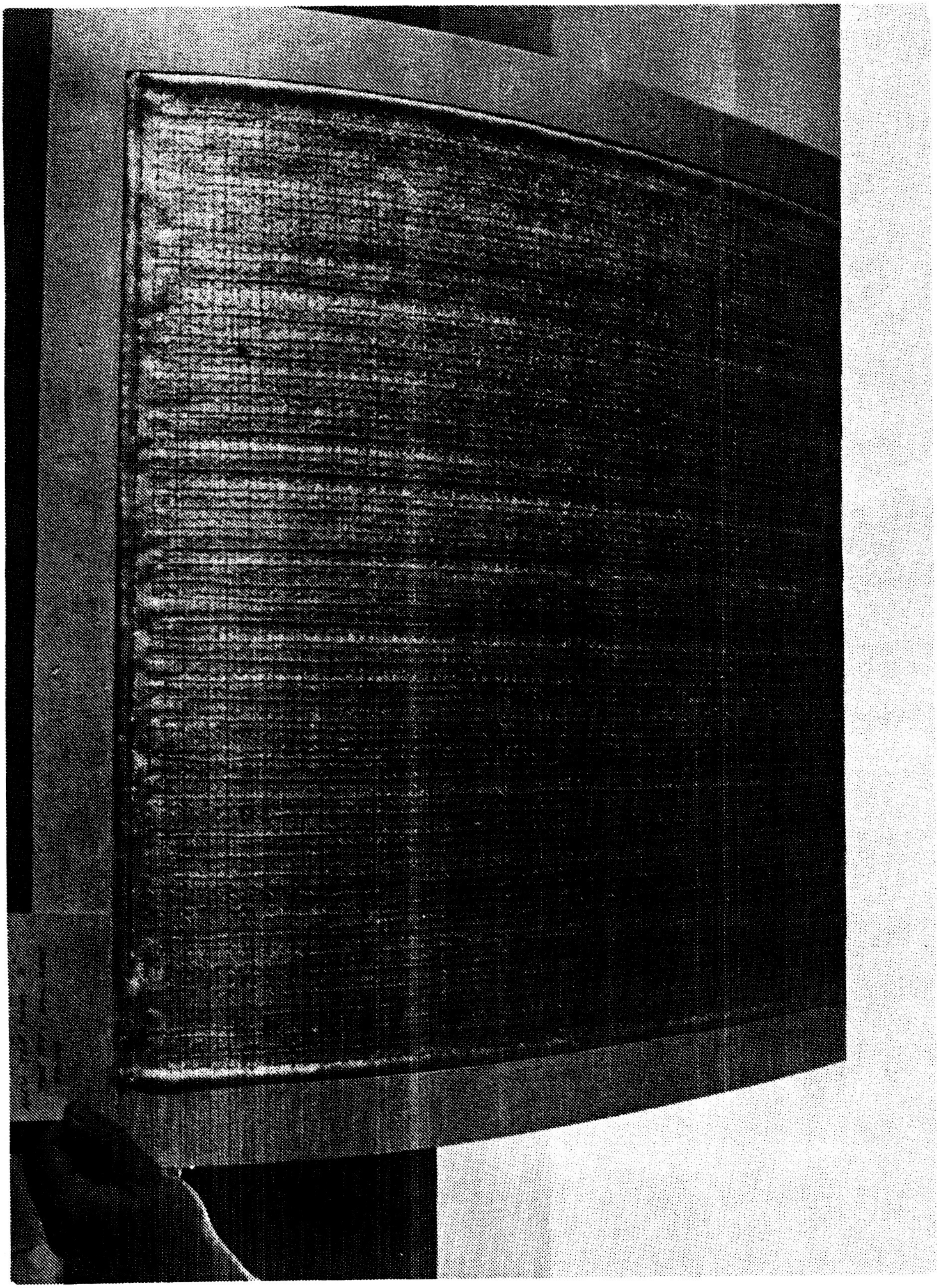


FIGURE 13g. Configuration D - Post-Test

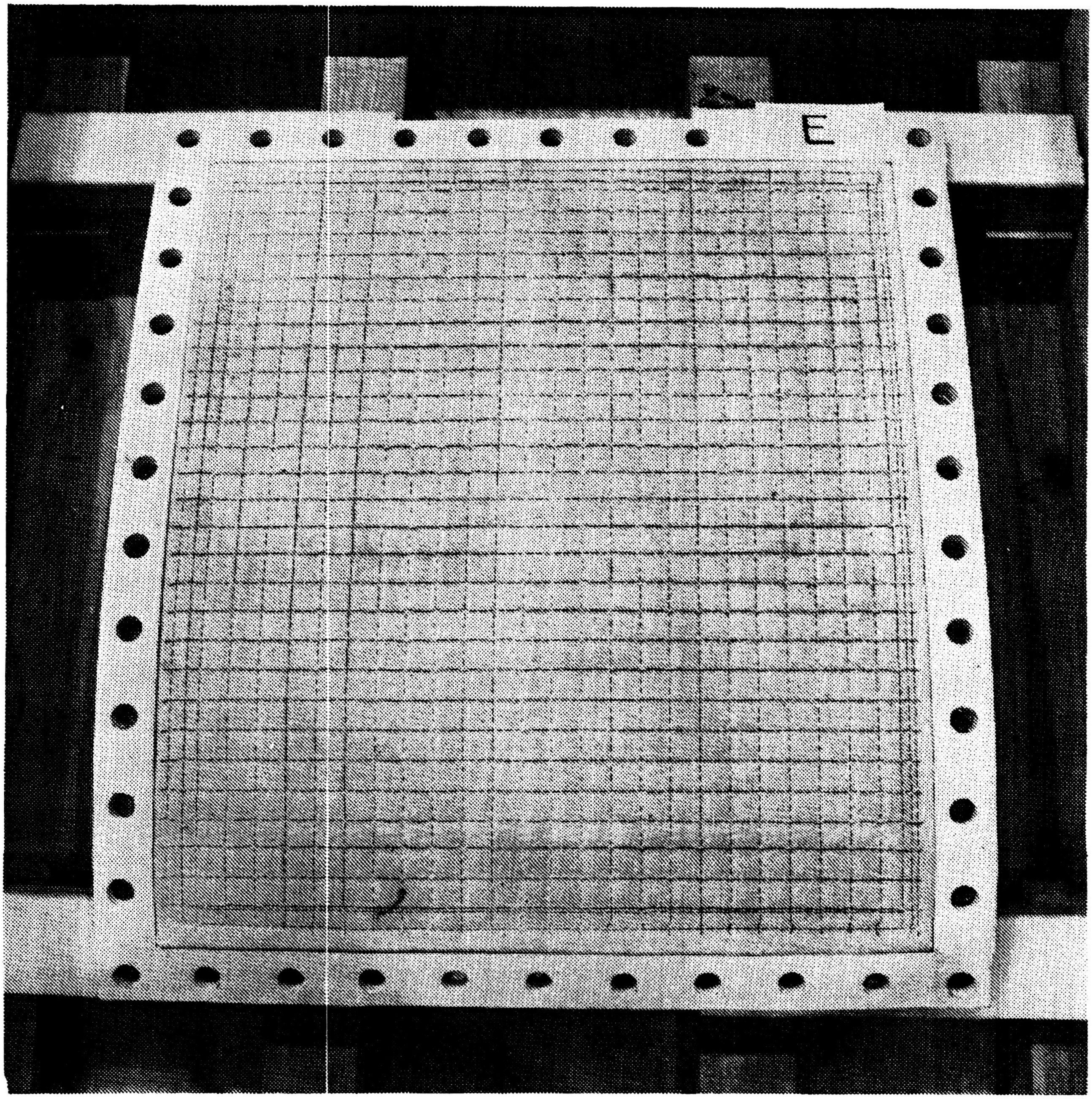



FIGURE 13h. Configuration E - Pre-Test

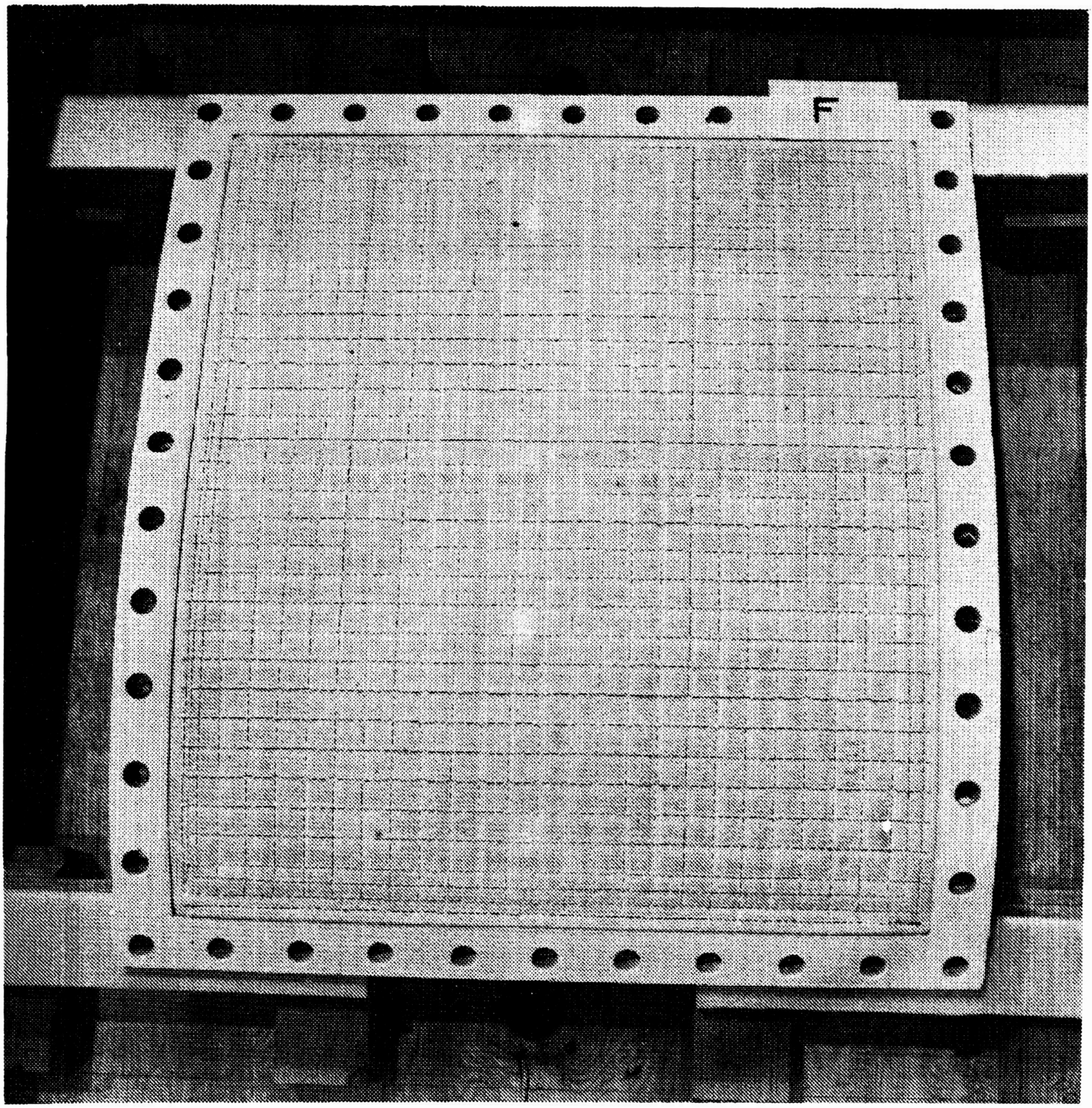



FIGURE 13i. Configuration F - Pre-Test

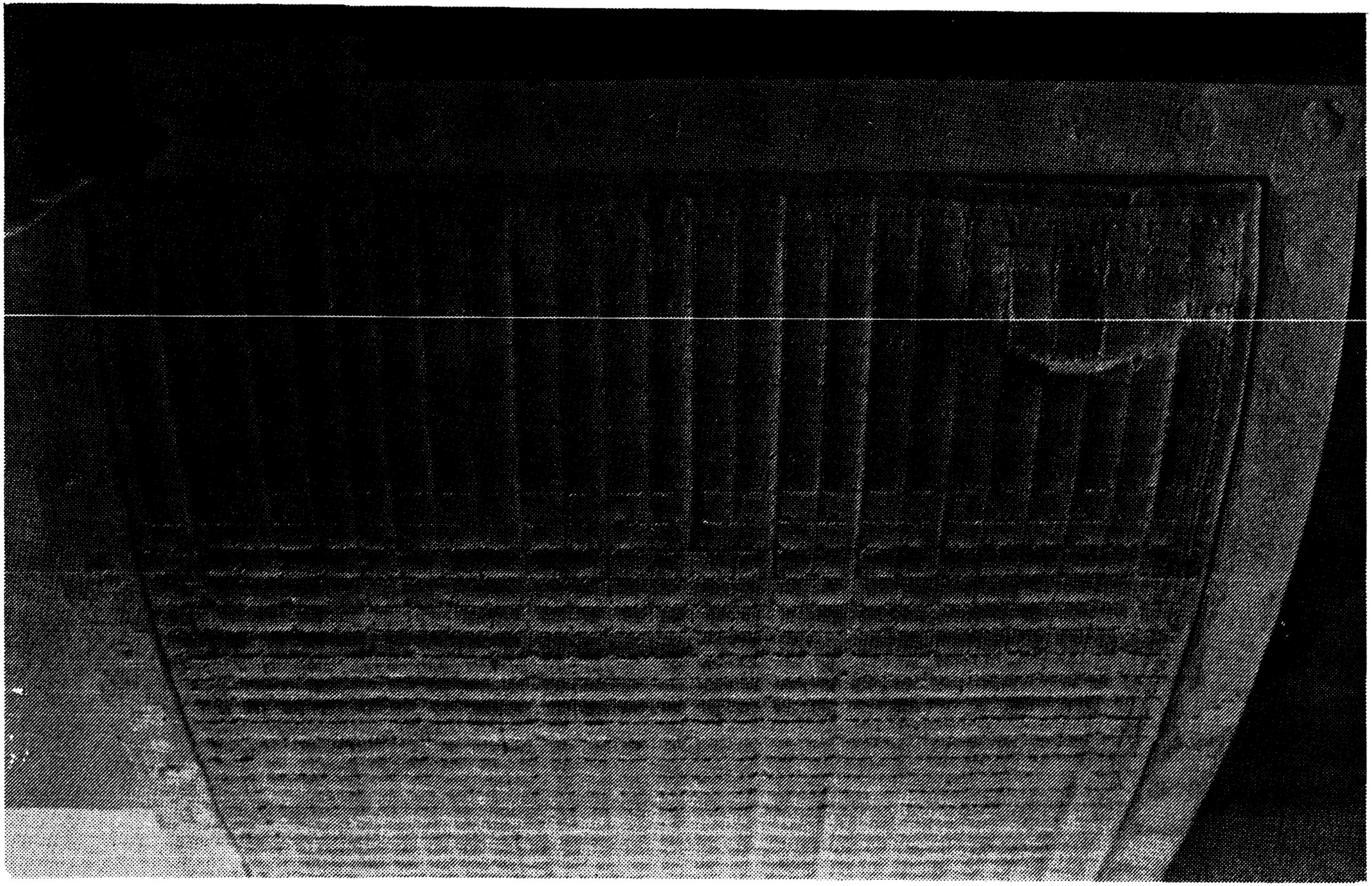


FIGURE 13j. Configuration F - Post-Test

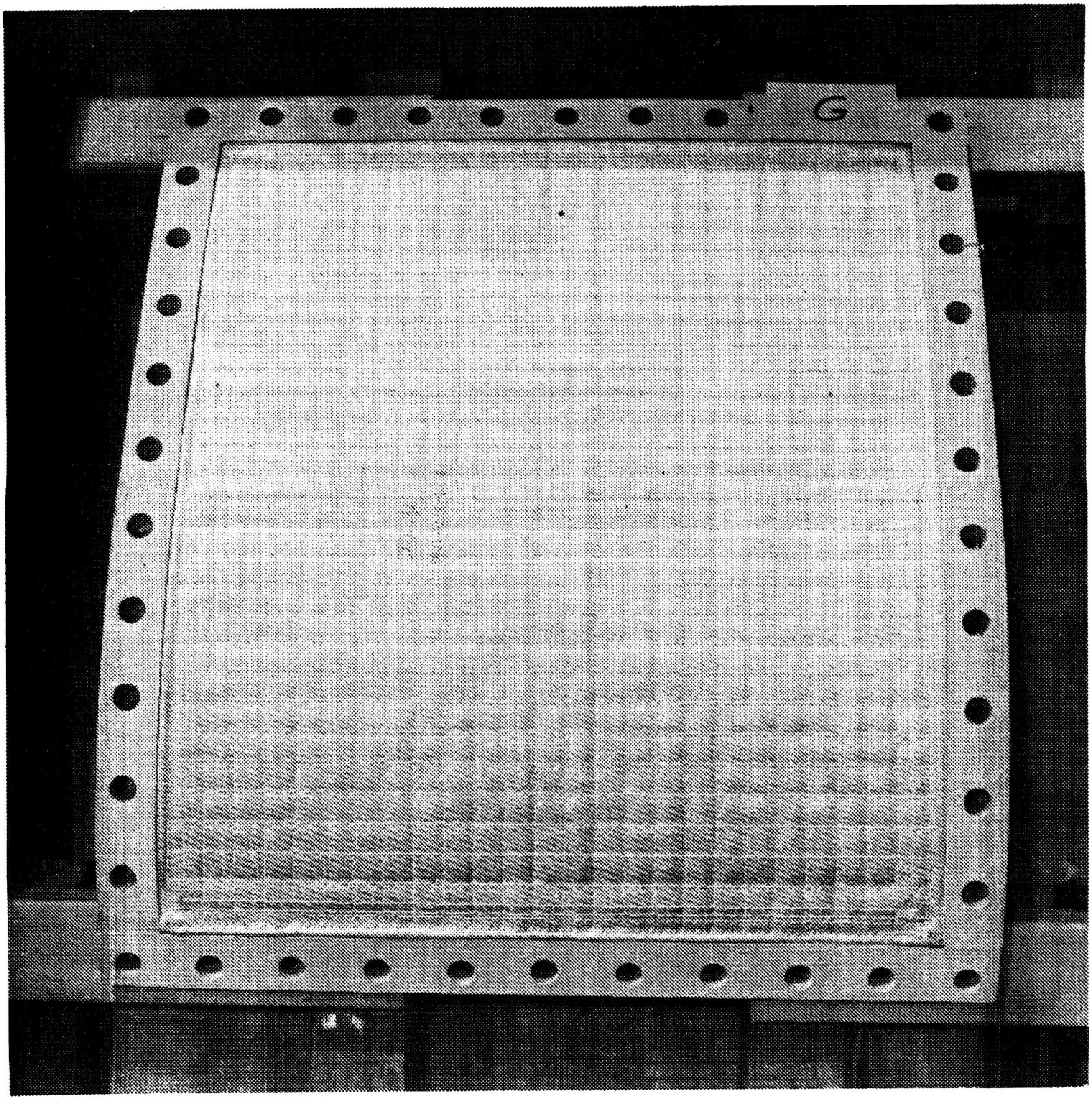



FIGURE 13k. Configuration G - Pre-Test

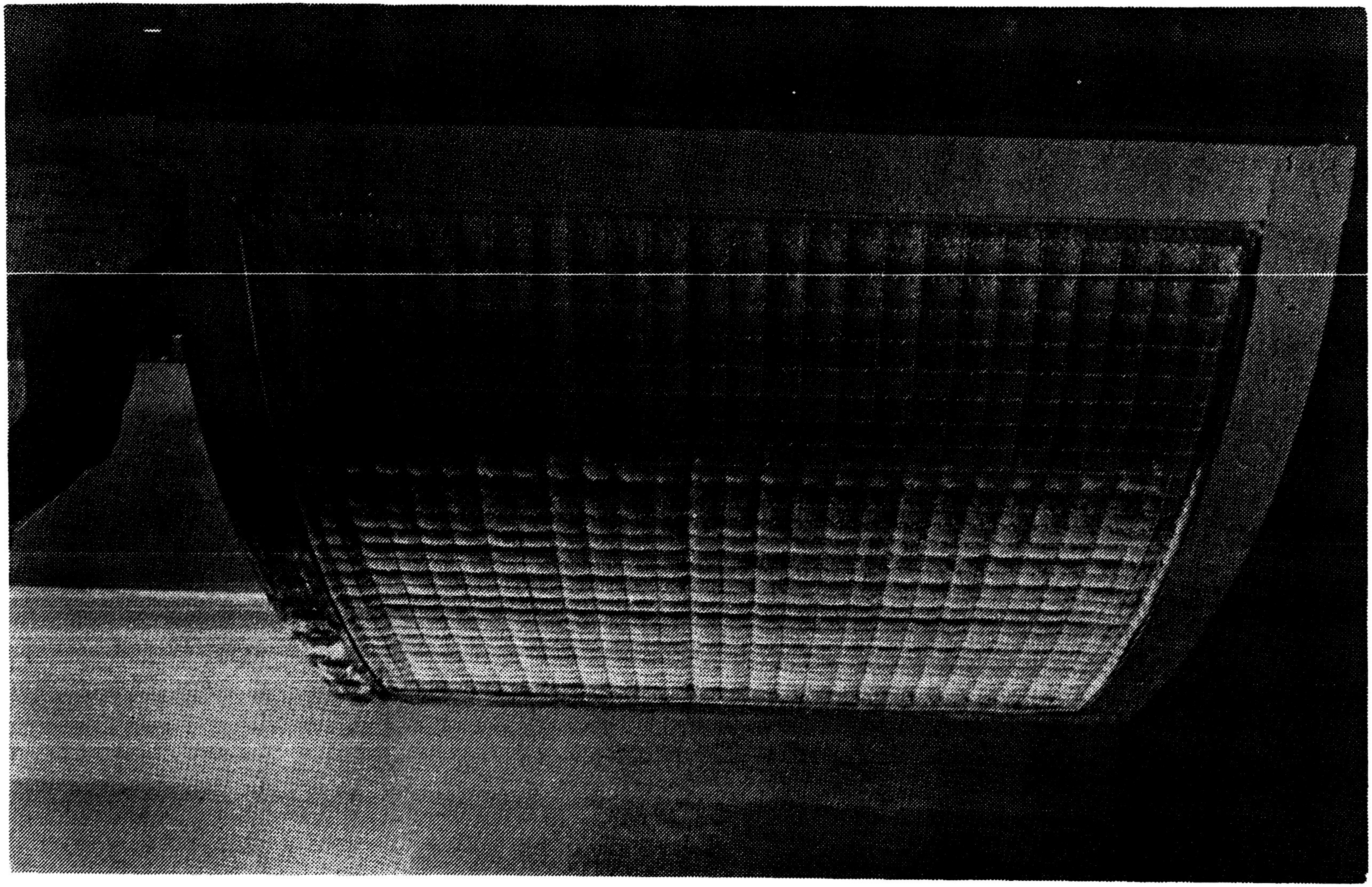


FIGURE 131. Configuration G - Post-Test

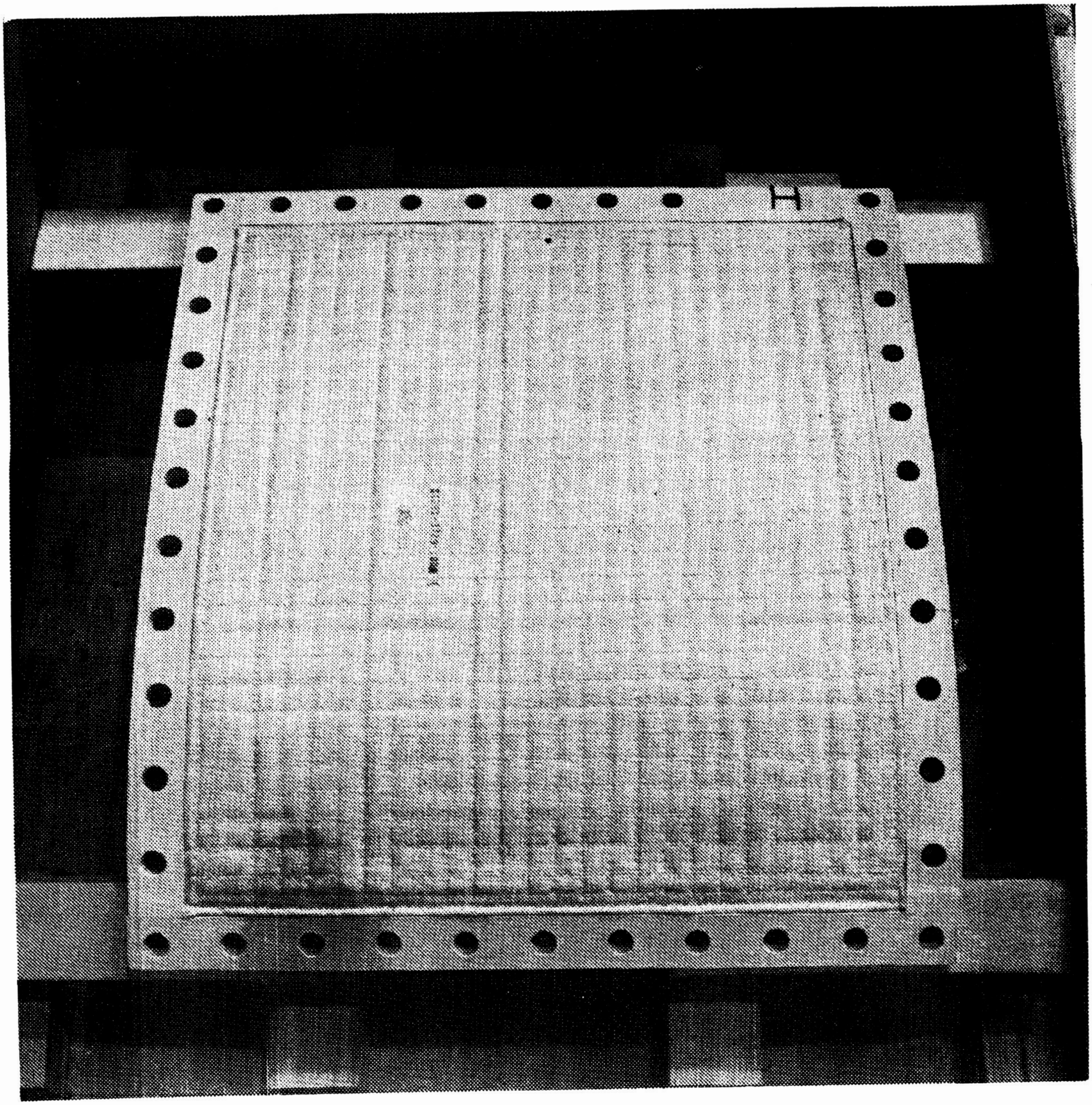



FIGURE 13m. Configuration H - Pre-Test

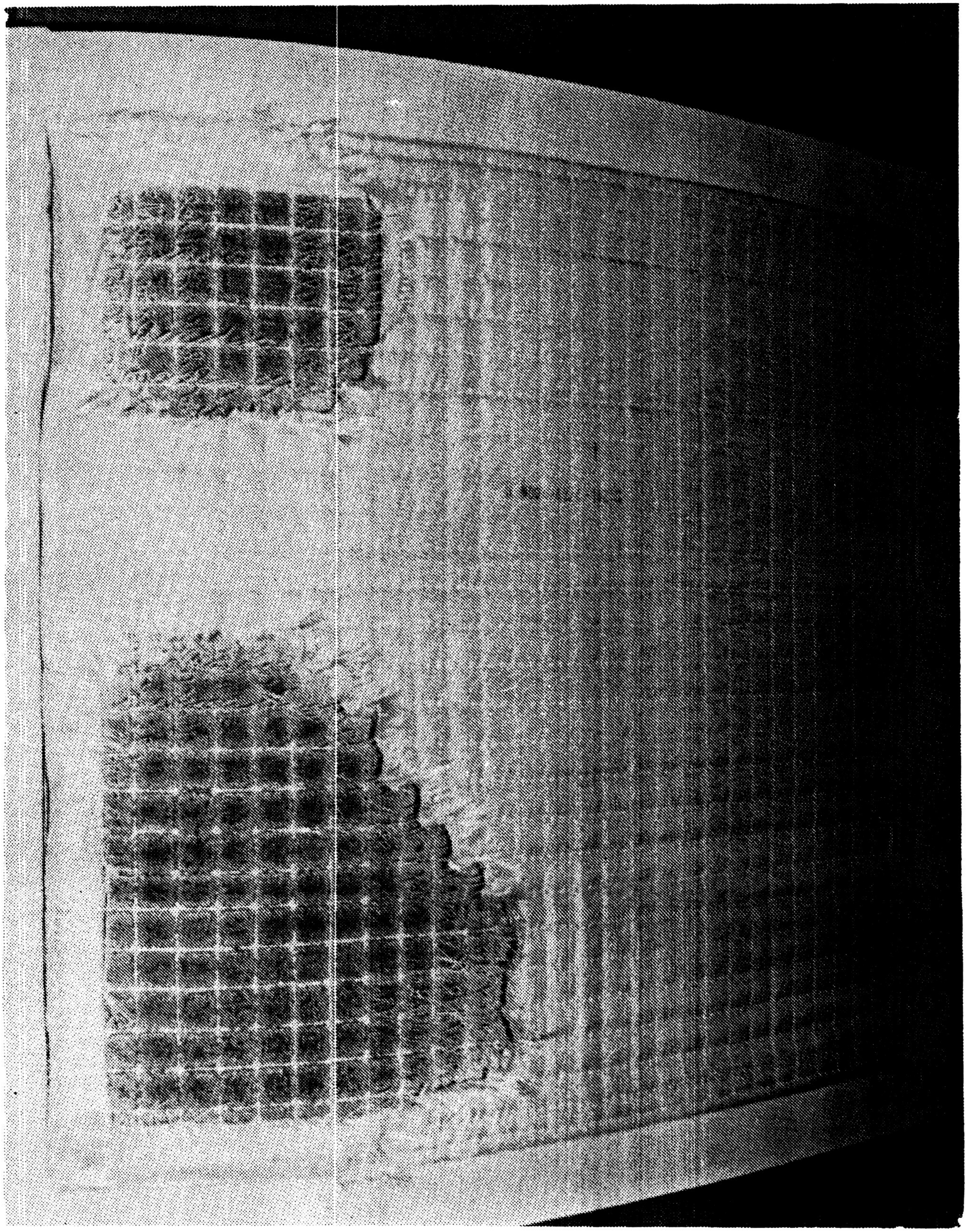


FIGURE 13n. Configuration H - Post-Test

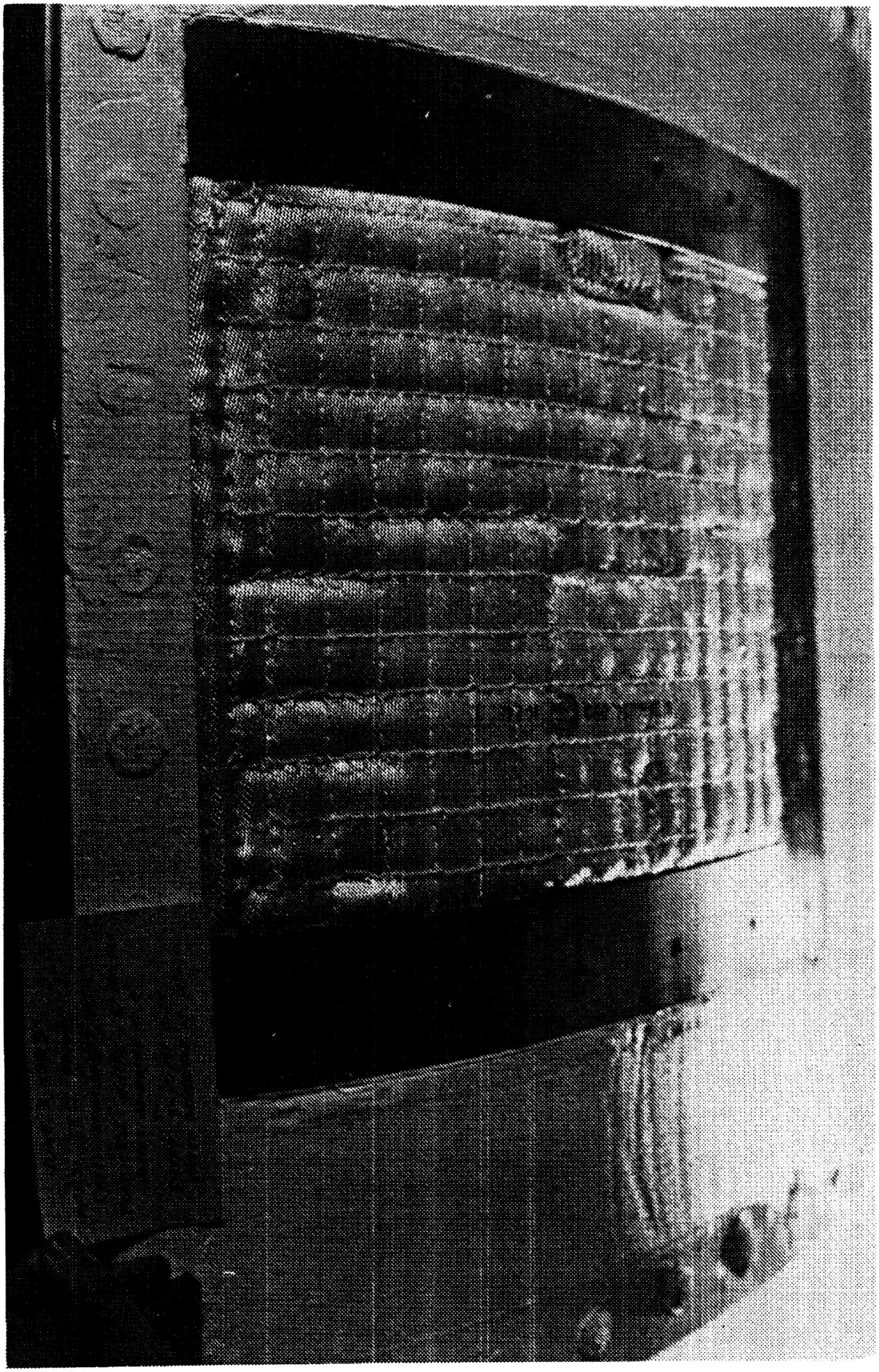


FIGURE 13o. Configuration J - Post-Test

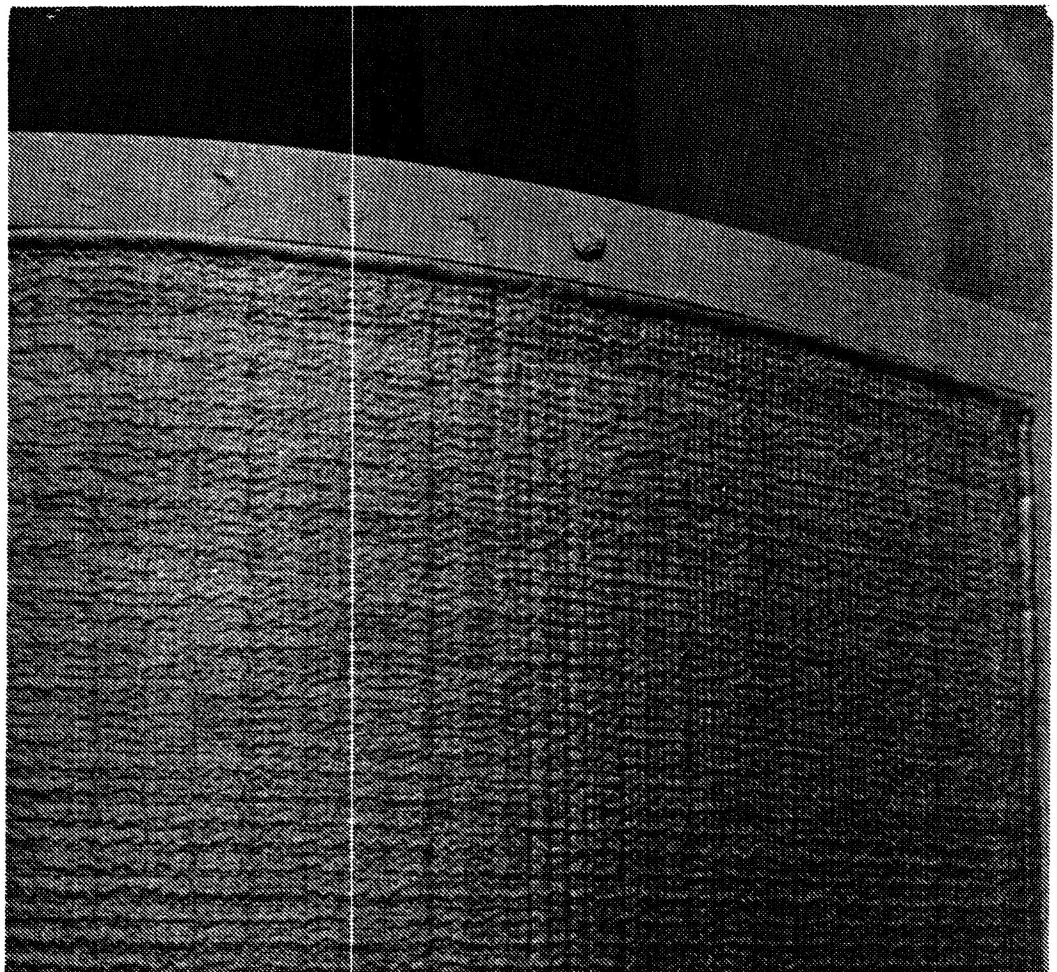


FIGURE 13p. Configuration 101 - Pre-Test

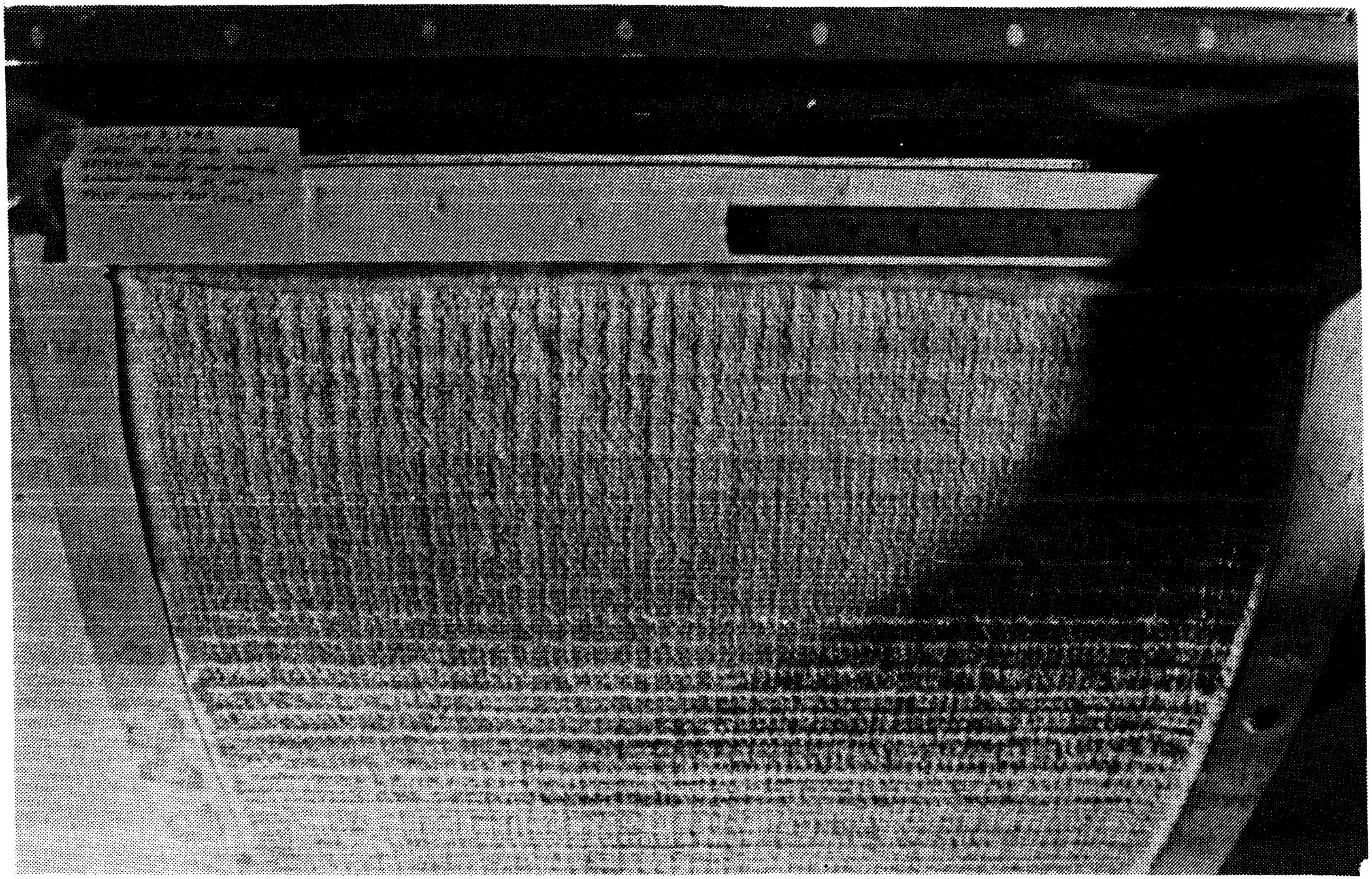


FIGURE 13q. Configuration 101 - Post-Test

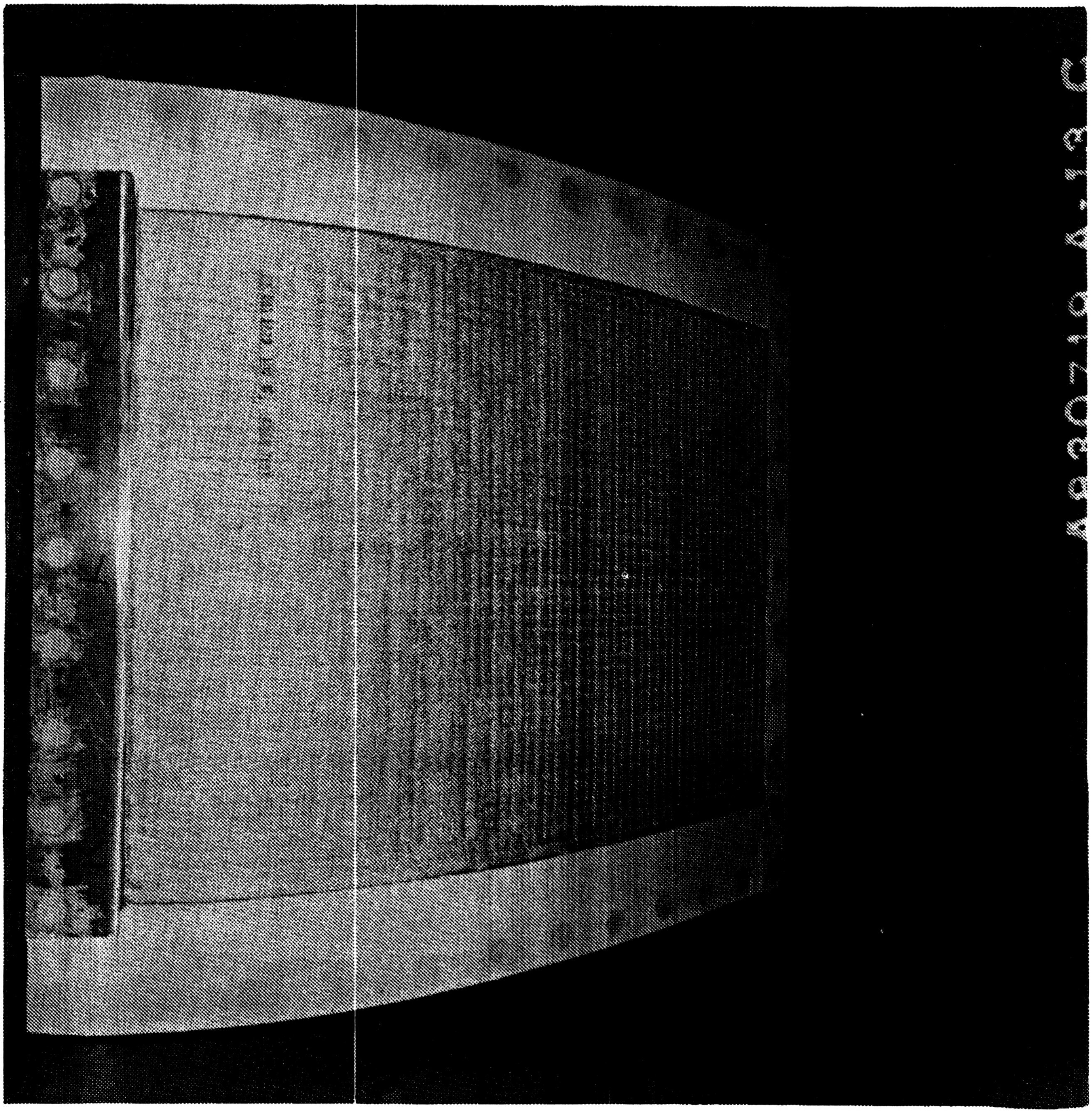


FIGURE 13r. Configuration K - Pre-Test

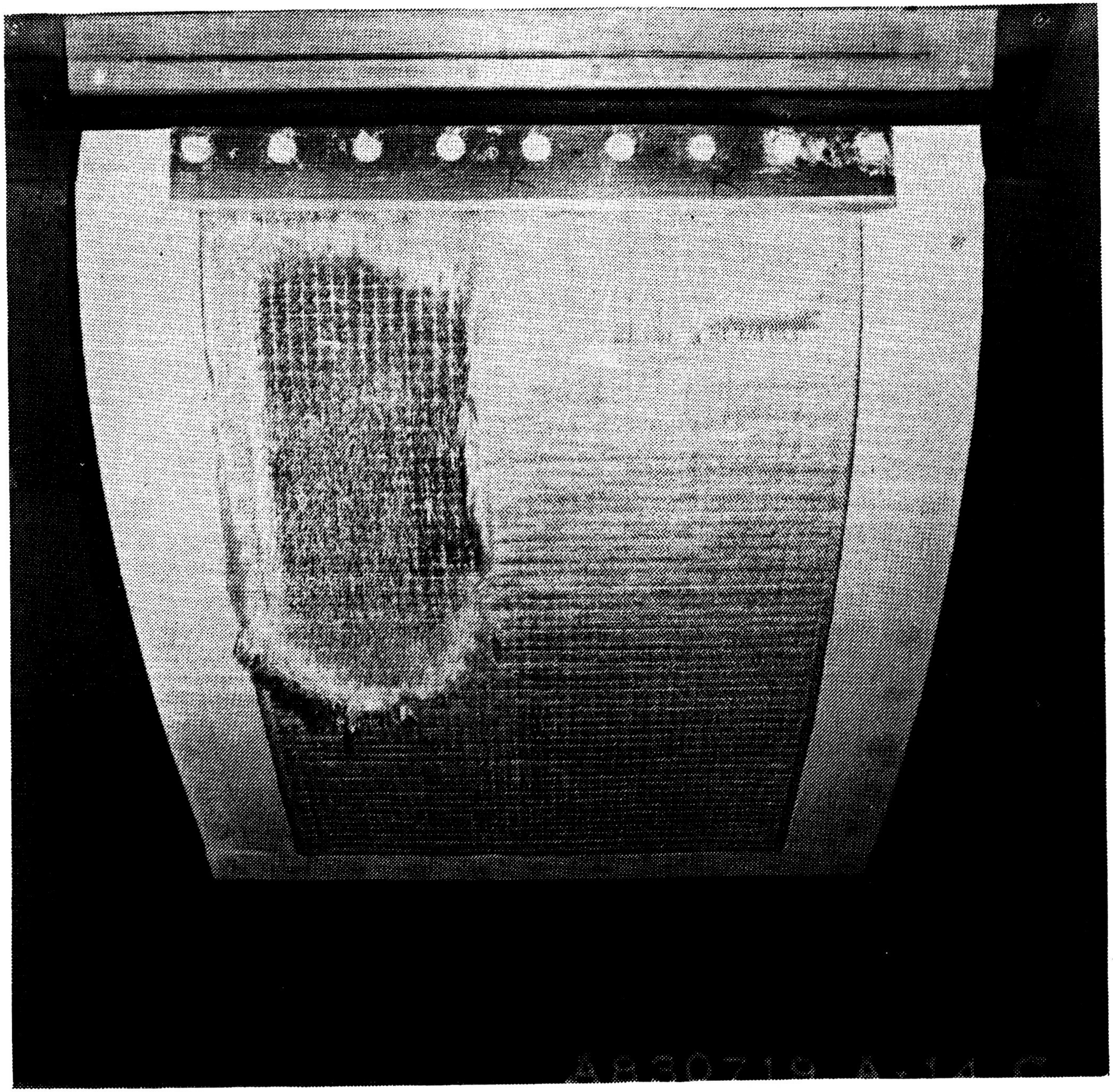


FIGURE 13c. Configuration K - Post Test

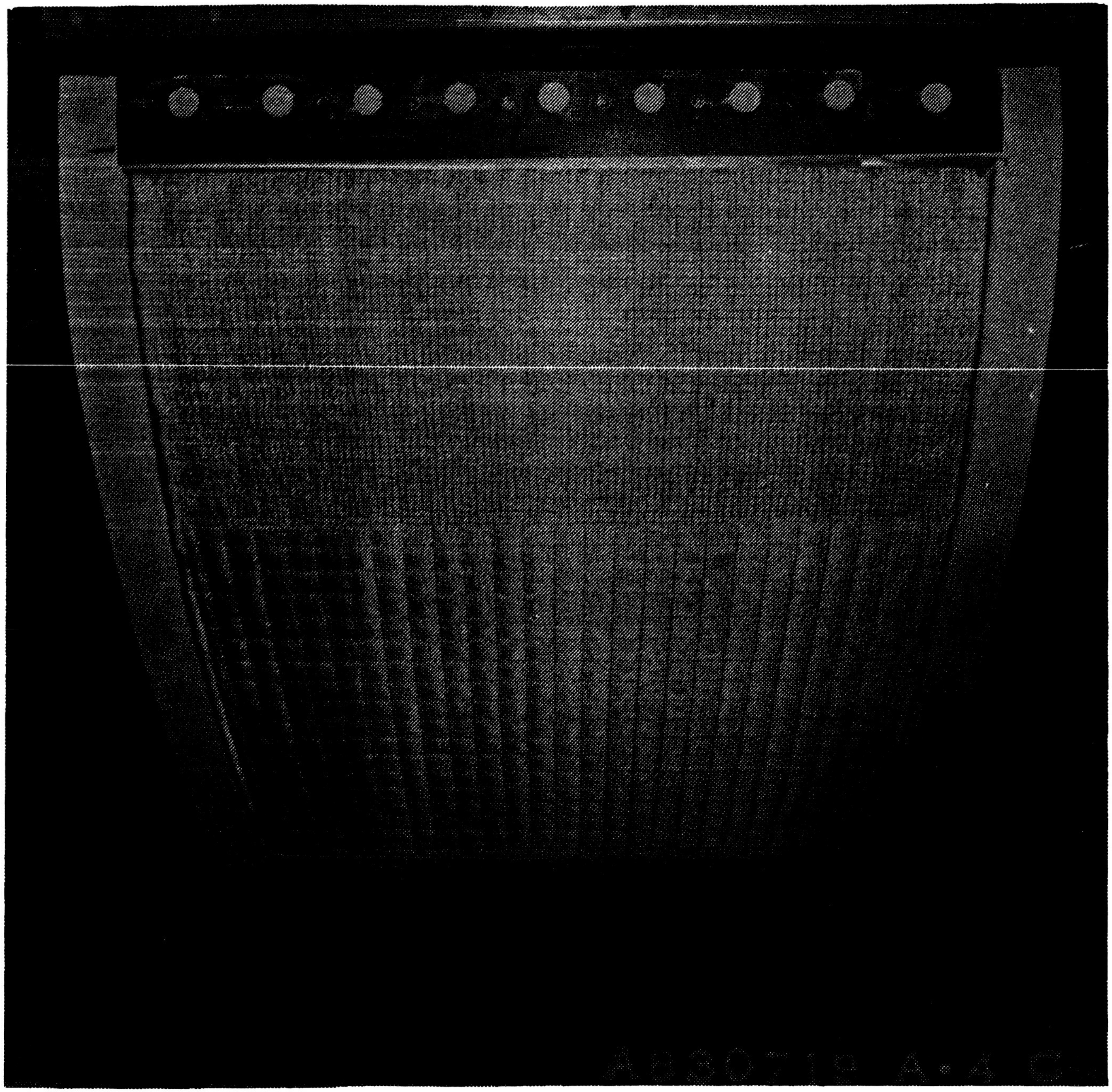


FIGURE 13t. Configuration L -Pre-Test

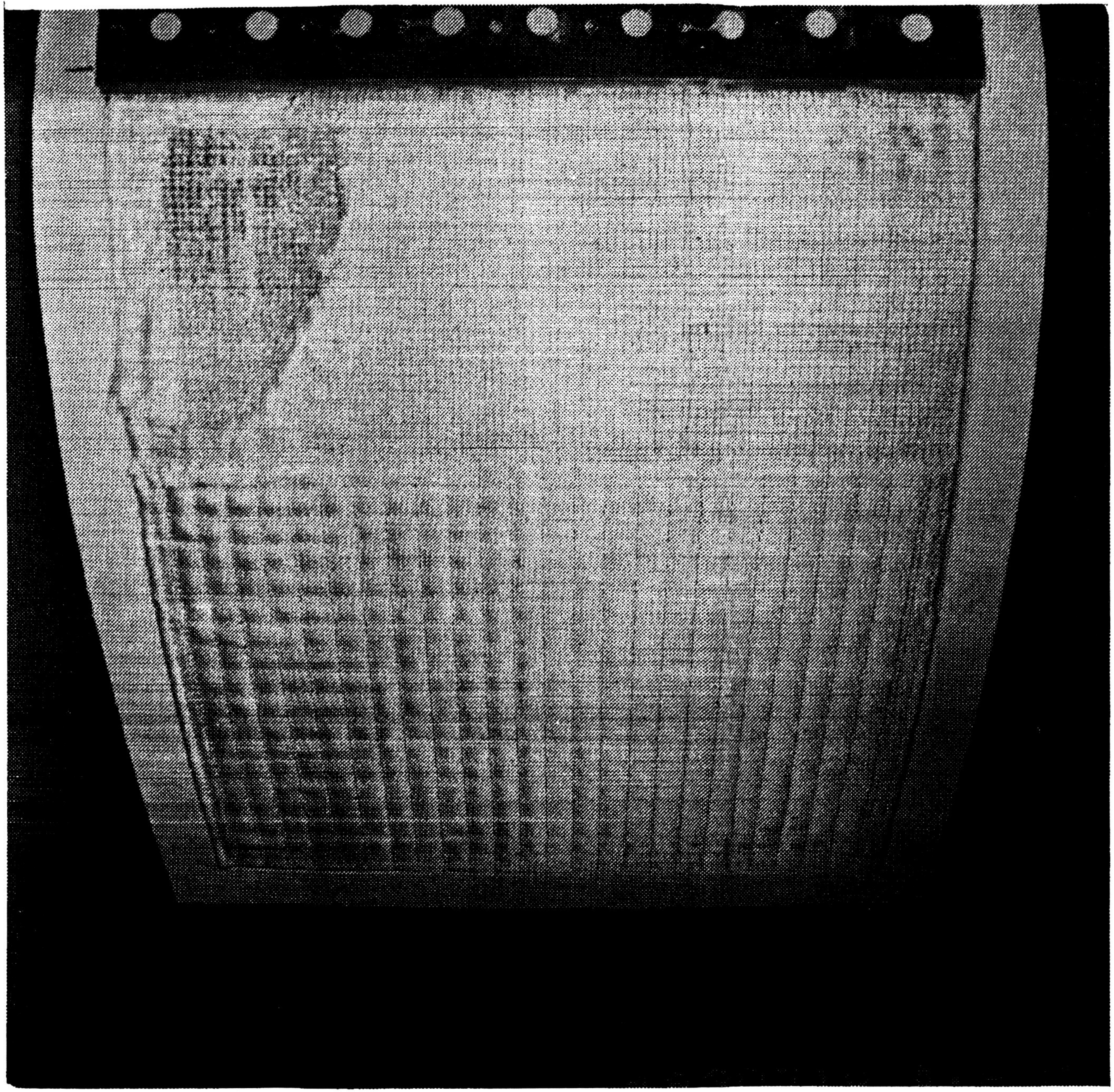


FIGURE 13u. Configuration L - Post-Test

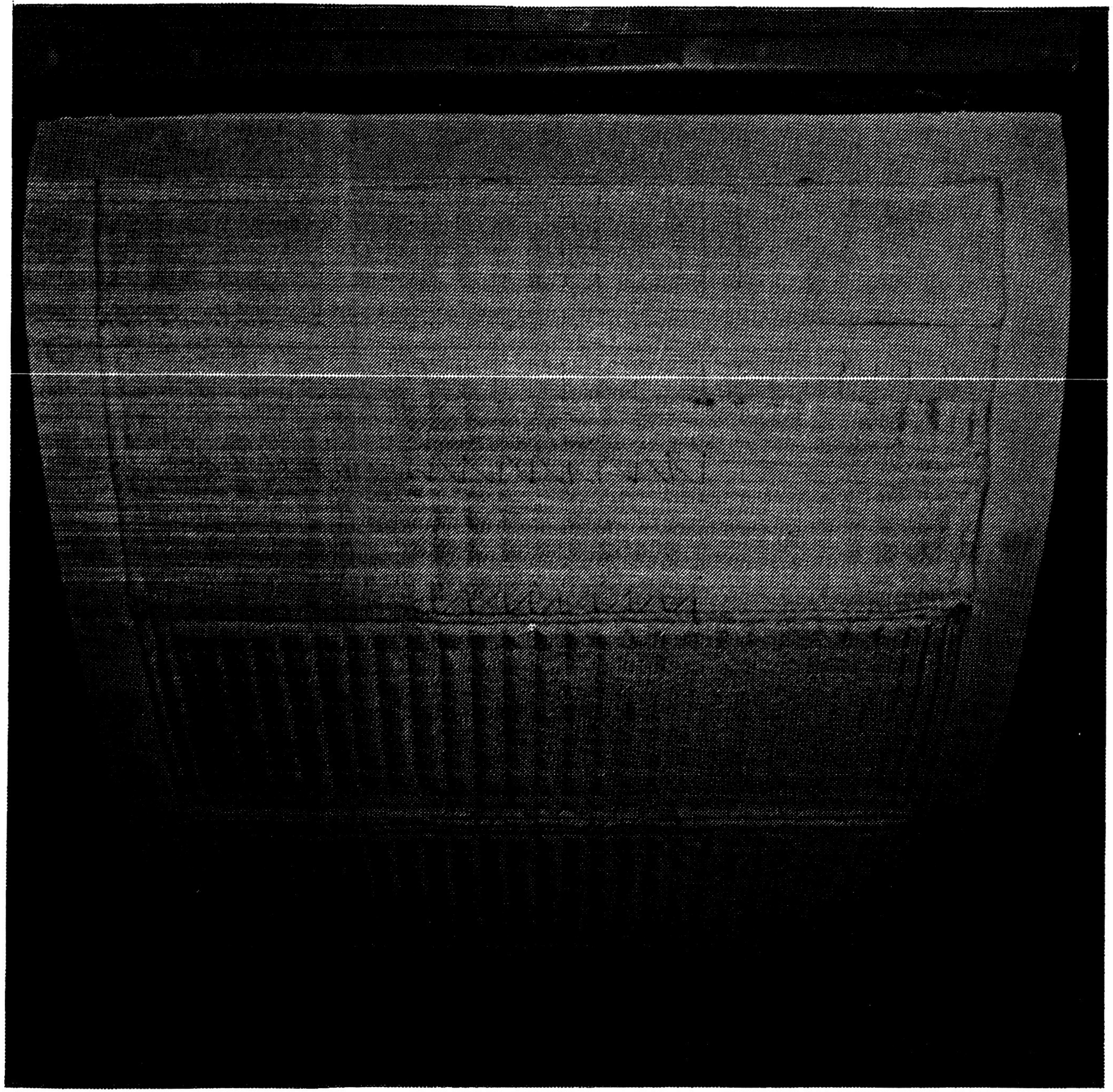


FIGURE 13v. Configuration 0 - Pre-Test

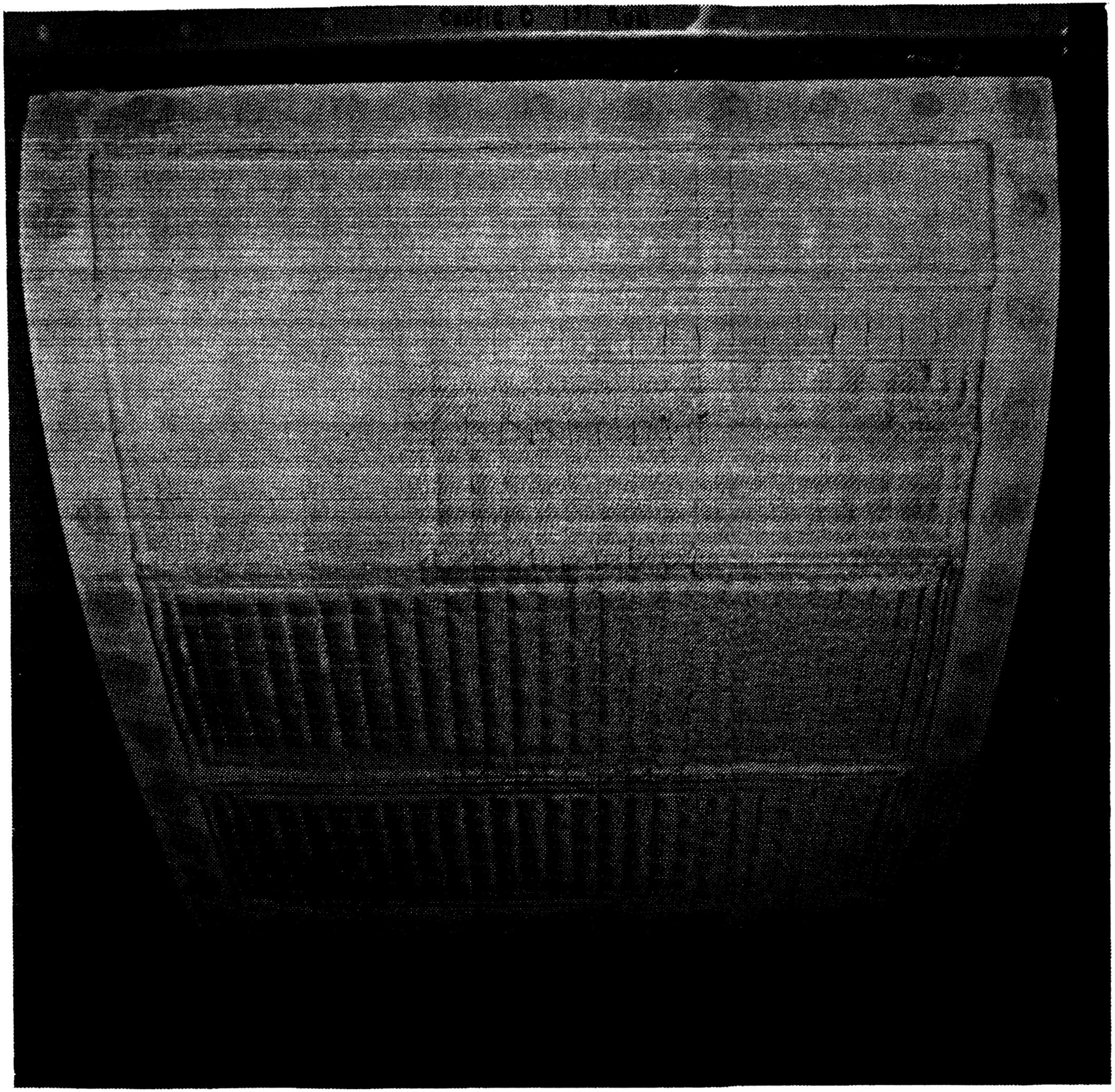


FIGURE 13w. Configuration 0 - Post-Test

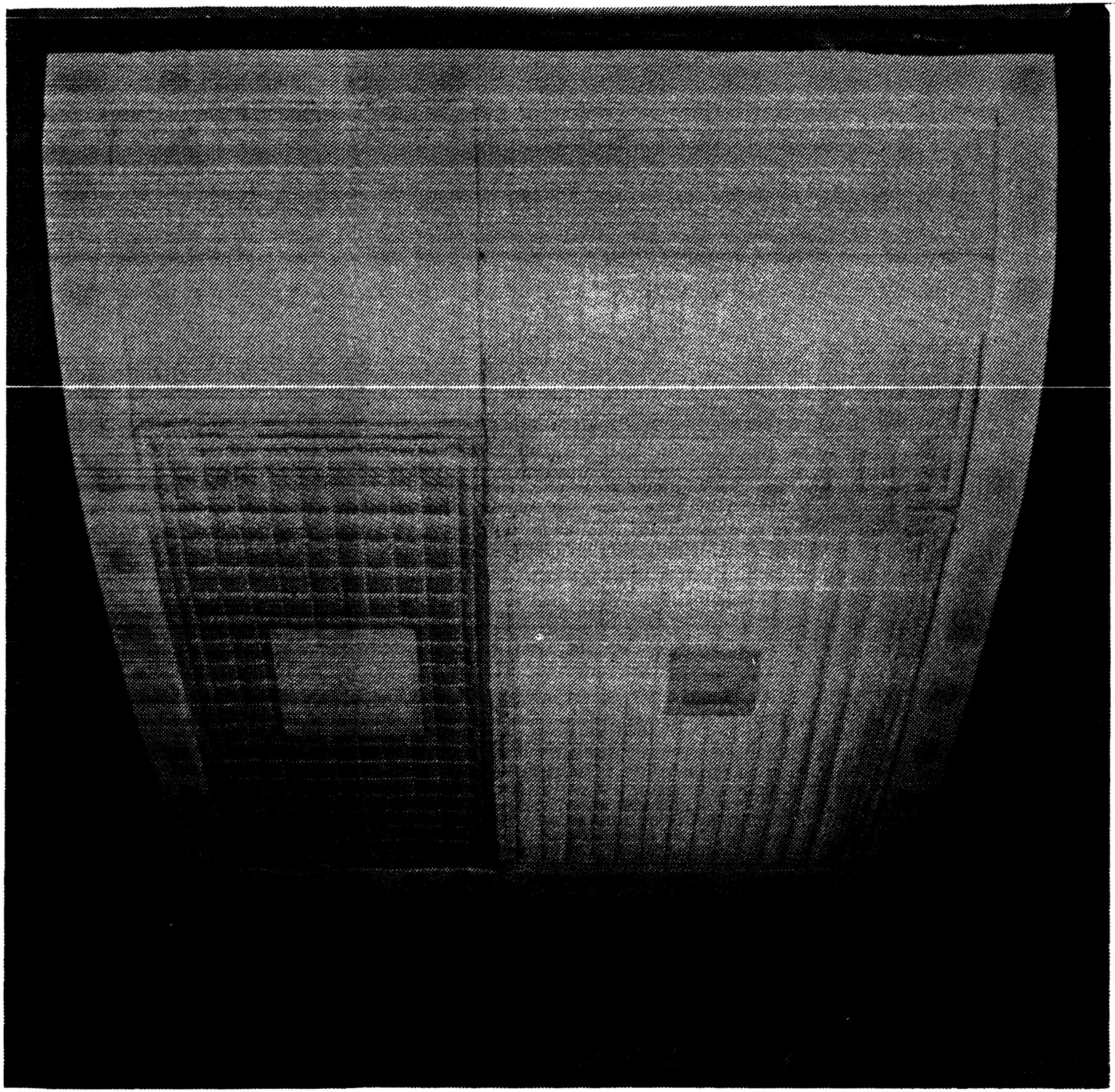


FIGURE 13x. Configuration N - Pre-Test

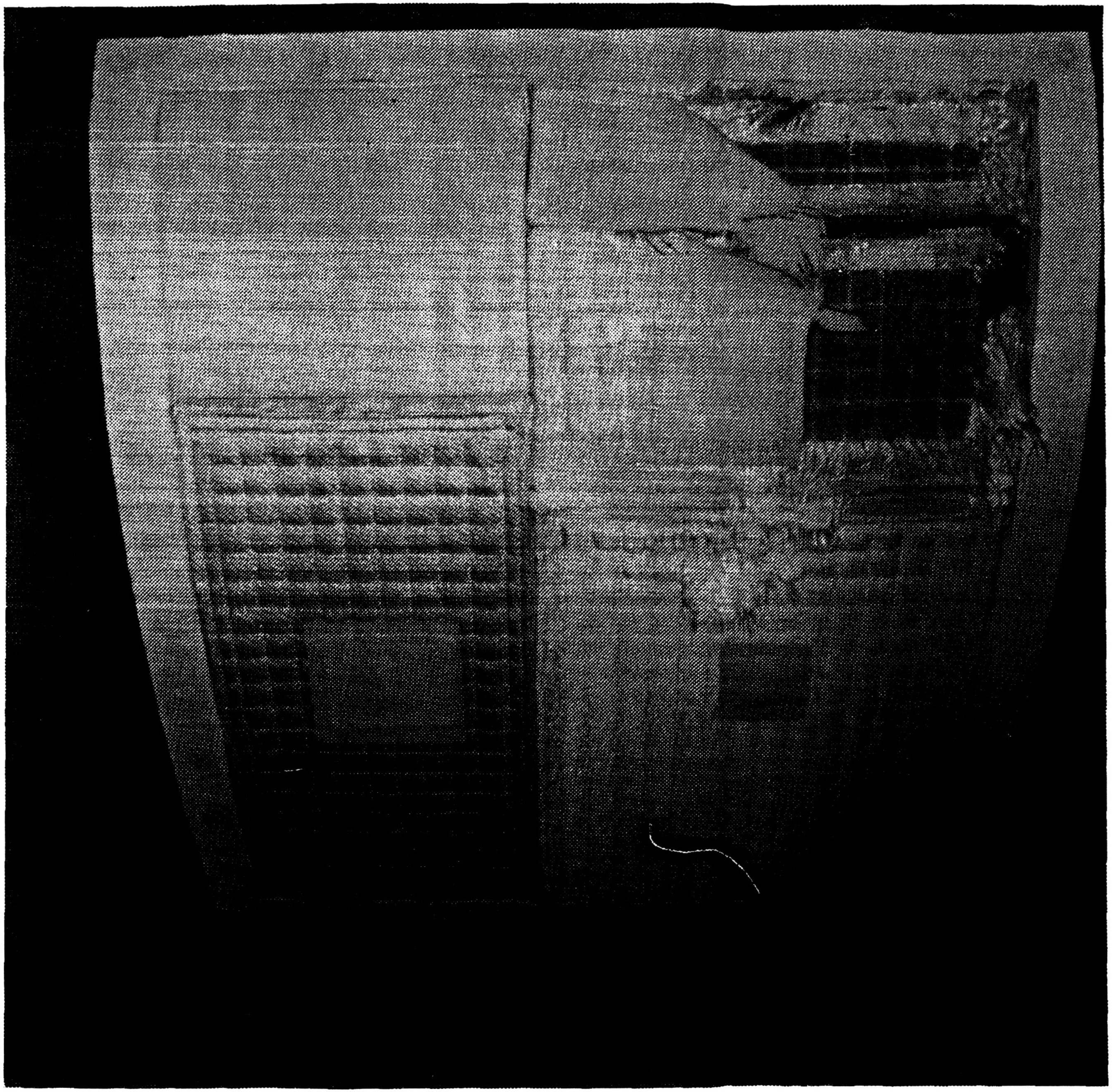


FIGURE 13y.  Configuration N - Post-Test

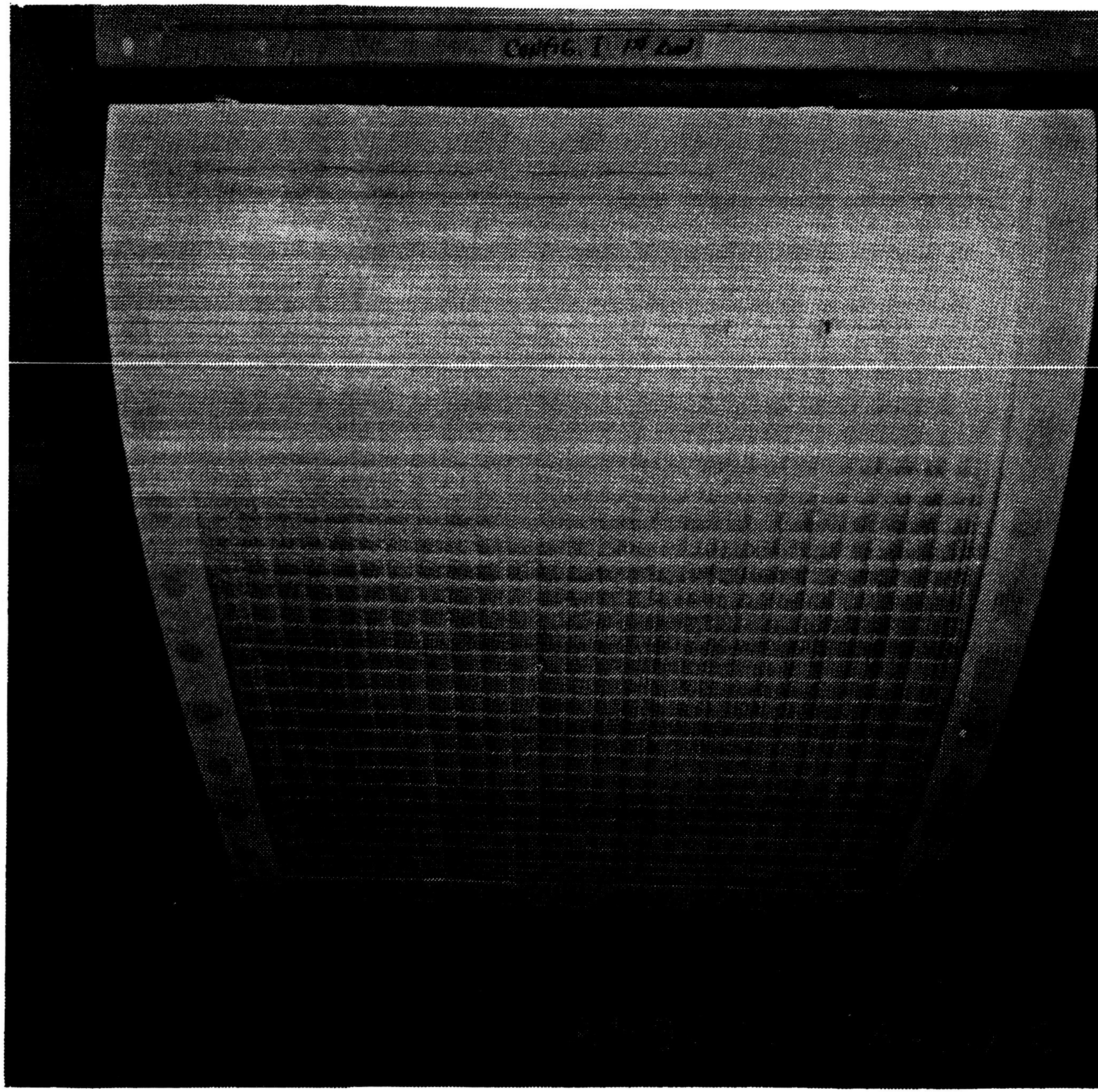


FIGURE 13z. Configuration I - Pre-Test

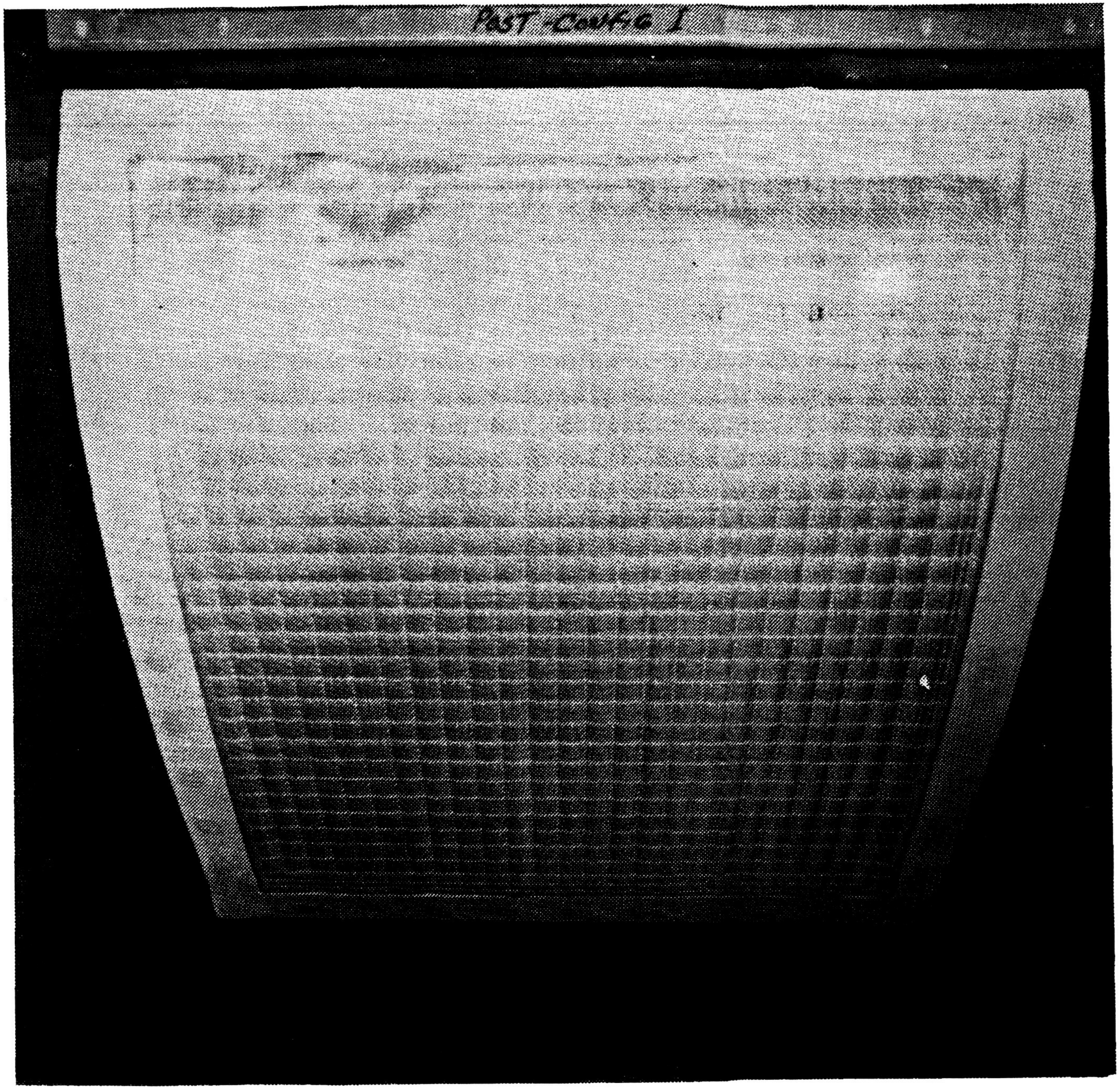



FIGURE 13zz. Configuration I - Post-Test

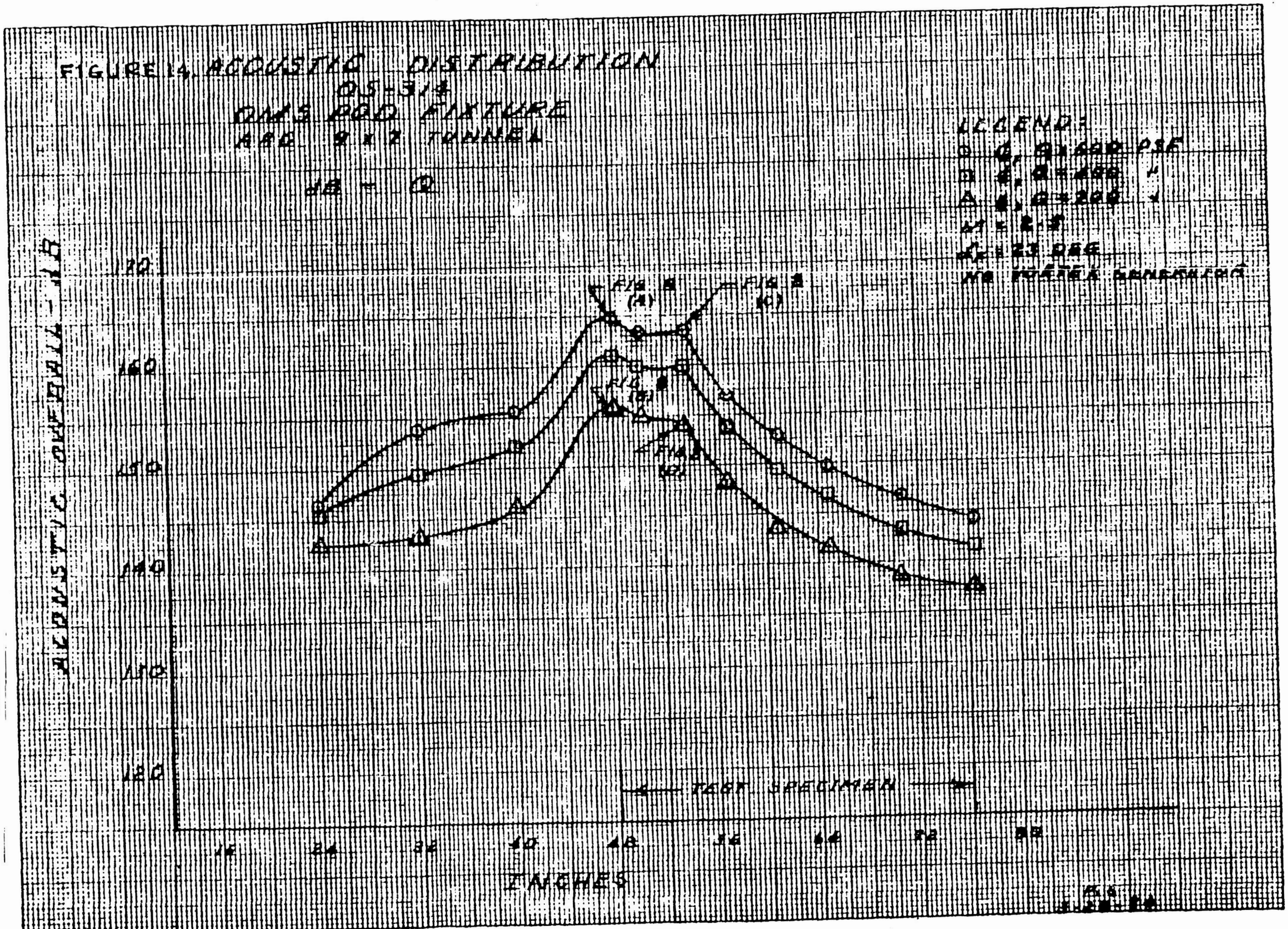



FIGURE 14. ACOUSTIC DISTRIBUTION

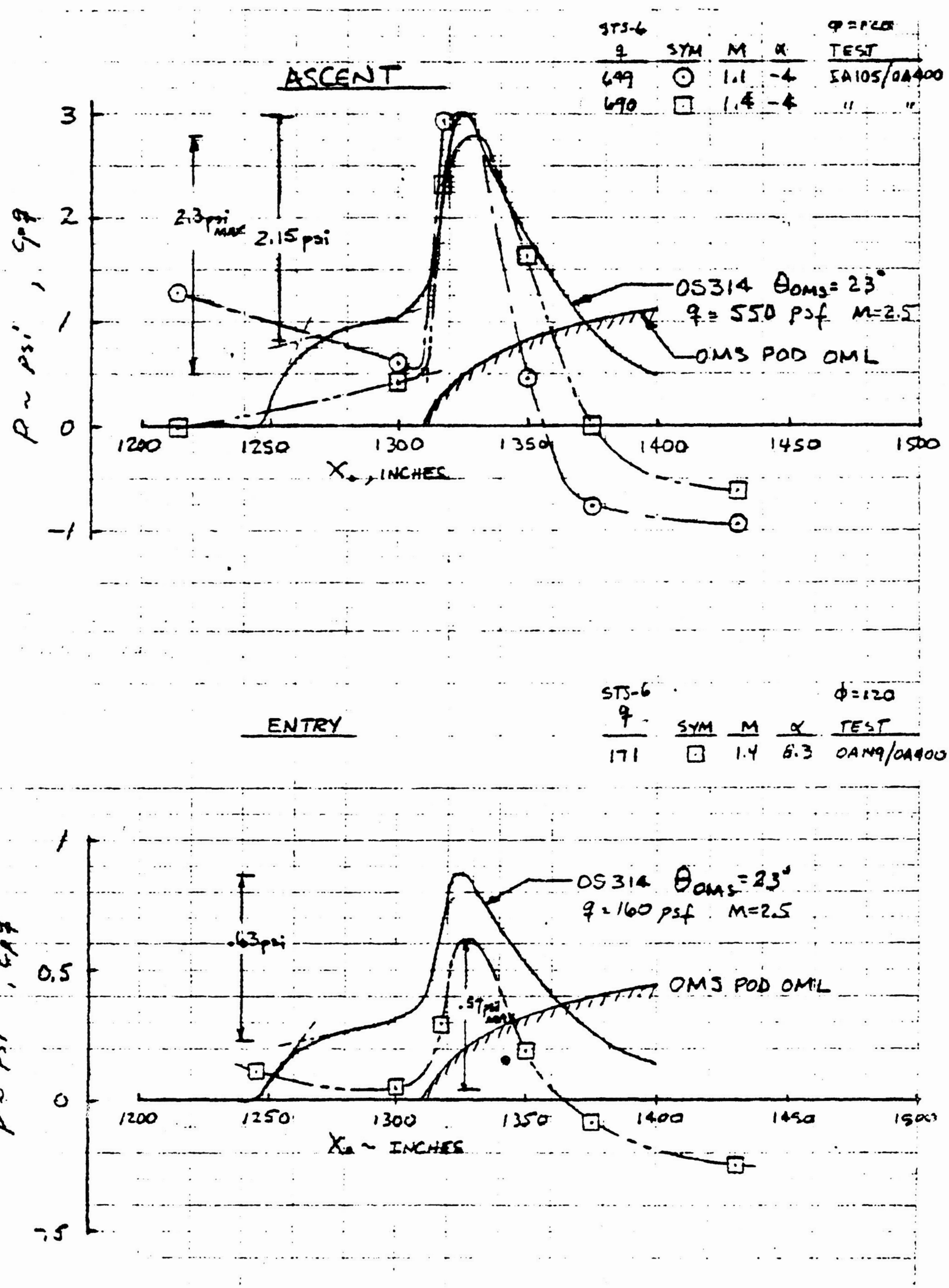



FIGURE 15. ASCENT & ENTRY (w/o VG) STATIC PRESSURE PROFILES

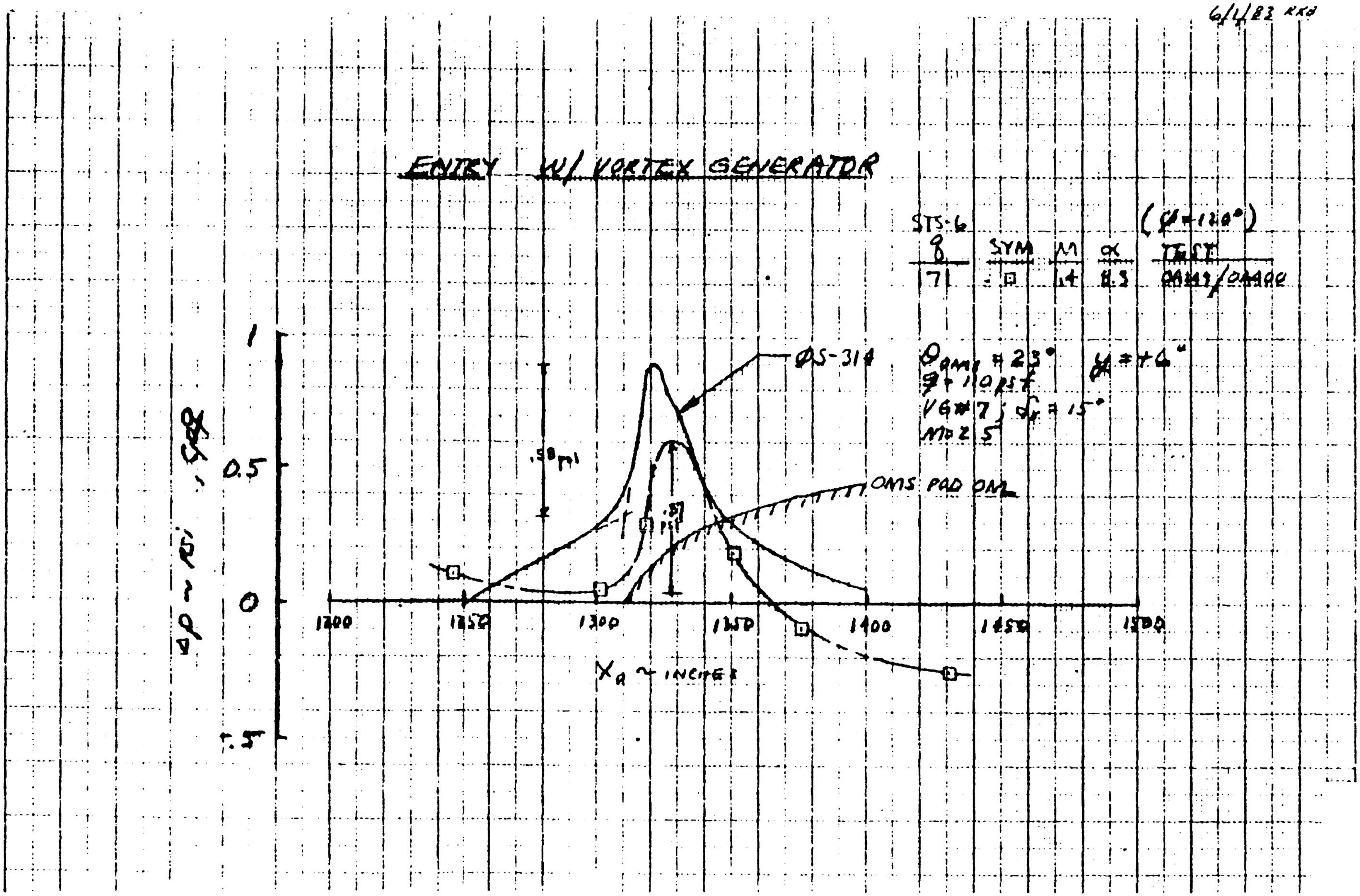



FIGURE 16. ENTRY (w/VG) STATIC PRESSURE PROFILE

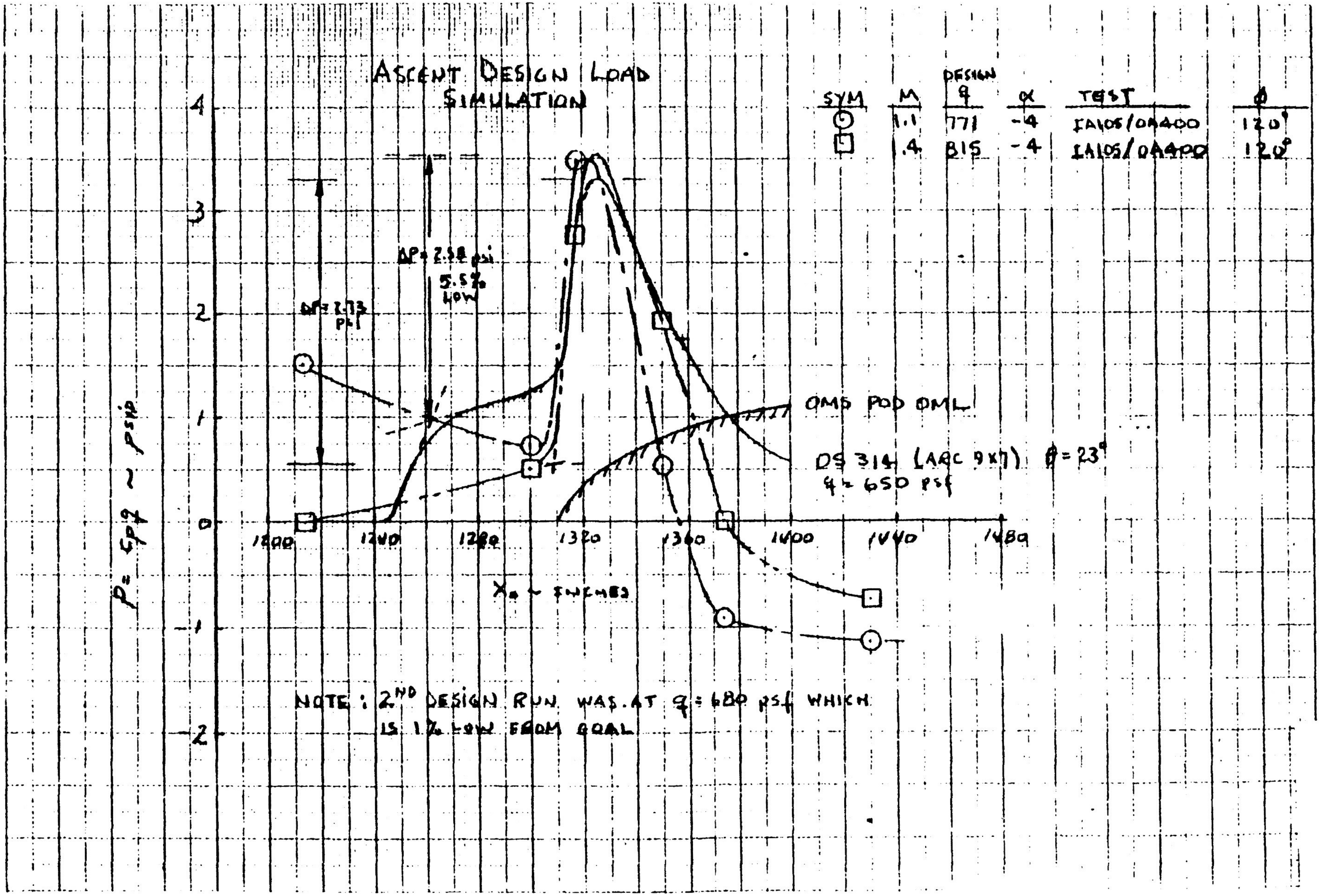



FIGURE 17. DESIGN ASCENT STATIC PRESSURE PROFILE

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FIGURE 18.

WIND TUNNEL / FLIGHT DYNAMIC PRESSURE CORRELATION